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COMPARATIVE ANALYSIS OF
HISTORICAL STUDIES
ANNEX VOLUME III

HISTORICAL TRENDS RELATED TO
WEAPON LETHALITY

15 October 1964

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HISTORICAL EVALUATION AND RESEARCH ORGANIZATION
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HISTORICAL TRENDS RELATED TO WEAPON LETHALITY

Comparative Analysis of Historical Studies (Annex III)

A Report prepared for the Advanced Tactics Project of the Combat Developments Command, Headquarters US Army, under Contract No. DA 30-069-AMC-647(X), dated August 28, 1964

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Historical Evaluation and Research Organization
2233 Wisconsin Avenue, N. W.
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15 October 1964

COMPARATIVE ANALYSIS OF HISTORICAL STUDIES
(Annex Volume III)

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Effect of Increased Weapon Lethality on
the Conduct of War
(Annex III-A)

by

Theodore Ropp

GENERAL

The most significant feature of the historical process by which weapons of increased lethality affected the general conduct of war was its almost glacial slowness. The usual civilian explanation that this was chiefly because of the inherent conservatism of the professional soldier might be the first casualty of the present report, although it could take several generations before this idea becomes acceptable in civilian circles, since civilian comprehension of what military men really do may be inversely related to military professionalization.

Any careful and systematic exploration of the general reasons for the slow spread and adaptation of new military techniques over the last 30 centuries will show that this was due to numerous social factors, some of which are still relevant and some of which have been overcome or compensated for in certain modern societies.

The most important fact is that historically the process of military innovation is discontinuous. This, in turn, reflects two basic discontinuities. The first was in the processes of technological and scientific change; the second was the alternating periods of war and peace.

During the many centuries in which invention was the prerogative of a few gifted individuals or of often illiterate craftsmen, all technological change tended to be discontinuous, partly because of the secrecy in which both craftsmen and scientists shrouded their "mysteries" and partly because of a host of class differentiations and resulting compartmentalization among various kinds of craftsmen, scientists, scholars, politicians, and

soldiers. In spite of contrary cries of alarm, it has been only recently that this compartmentalization has begun to break down. Modern states have been able to enlist business, research, military, and administrative institutions capable of exploiting the scientific method in work toward common goals such as military effectiveness. Although inhibiting social and political factors still exist, with all these institutions now in existence a process of continuous development has become possible.

Because of the compartmentalization that previously existed, the history of both technology and military innovation contain many examples of reinvention and rediscovery, for no other reason than the loss of previous historical experience. The history of the galley is one of the best examples. For nearly two thousand years the craftsmen who built these quite sophisticated military machines repeatedly rediscovered all the possible combinations by which more power might be obtained from various arrangements of rowers.

Monastic chroniclers and modern liberal historians were not the only ones who were little interested in the key details of military and technological history. With the major exception of the great Greek historian Polybius, very few historians before the 19th Century were primarily interested in finding out "what actually happened." They were usually more interested in drawing "lessons" to prove some particular military theory or in glorifying or vilifying some political, religious, or military system, or some individual monarch or commander. As a result, most of the key details both of military inventions and of their adoption in battle were lost because they were not felt worthy of being recorded. Even after the application of scientific methods to these two historical fields, national pride--as can be seen in many of the first official military histories*--has frequently distorted the record until the present day. If history is "funded experience,"** it is well for both the historian and his readers to realize how much of this funded experience has been irretrievably lost and how recent has been the development of the process of retrieving military and scientific experience in time for it to be of more than purely historical interest.

* See the interesting examples cited by Jay Luvaas, "The First British Official Historians," Military Affairs, XXVI, No. 2, Summer 1962, pp. 49-58, though he does not deal with one of the worst examples, the German official account of the Franco-Prussian War.

** The phrase so aptly used by the great British official historian Sir Keith Hancock in Four Studies of War and Peace in This Century, Cambridge, Cambridge University Press, 1961, p. 11.

A case in point is the fate, only a century ago, of the writings of the great French military critic Ardant du Picq. He was the first author in modern times to try to examine systematically what really happened in a small unit in battle. Yet his now classic Battle Studies* were almost completely misinterpreted for nationalistic reasons by the French critics of the next generation. His careful study of the key problem of fear, and his insistence that the new open order made the problem that of making the soldier wish to go forward, were gradually turned into the positively dangerous idea that morale and training alone could overcome the most lethal of the new weapons. Such nationalistic wishful thinking can still be found, of course. Soviet official historians are only now beginning to admit indirectly that all Soviet defeats were not wholly due to inferior equipment or the mistakes of Stalinist commanders.

The second basic discontinuity in military experience is of equal significance. For a variety of reasons warfare is both epidemic and endemic in modern history. The traditional chronologies recognize this fact. Their nodal points--1648, 1713, 1789, 1815, 1848, 1871, 1914, 1919, 1945, etc.--are the beginnings or the ends of major periods of war or revolution. Wars which do not fit these chronological patterns were often fought in "minor" theaters or by other than "major" powers. Their "lessons" were consequently ignored, as was the case with some of those of the American Civil War,** or turned out to be the "wrong" lessons, as was the case with many of those of the numerous colonial wars of both the early and the late 19th Century.

The armies of 1792 and 1914 and the major part of those of 1939 had not had extensive and recent combat experience. This was particularly the case with the junior officers and the men in the ranks. It was not compensated for by the extremely careful peacetime training of either the old Prussian army of 1792

* Published after his death in 1880 and translated into English several times, Harrisburg, Military Service Publishing Co., 1957, etc.

** See, for instance, Jay Luvaas, The Military Legacy of the Civil War: The European Inheritance, Chicago, University of Chicago Press, 1959.

or the new German army of 1914. As the actual combat operations of World War II and Korea recede, all thoughtful soldiers and historians must be constantly aware both of the necessity and of the hazards of substituting history, training, and scientific analysis for actual combat experience. This problem is obviously complicated by quantum jumps in weapon lethality. We do not really know very much about what punishment modern industrial societies can suffer and still remain viable.

The many attempts to evaluate such punishment on a statistical basis remain quite unconvincing because of the lack of real historical evidence.* All such studies still rely on gross historical economic indices in dealing with the recoveries of economies which--in both the United States and the Soviet Union--are increasingly dependent on the long-range transportation of electric power, as well as of food and basic raw materials. While authors of such studies** have shown somewhat greater willingness to consider the unquantifiable problems of social disintegration, both their implicit and explicit assumptions must still rest on the experience of this century with economies whose recoveries were massively supported from undamaged outside areas and by transportation networks which had carried the victorious armies into the defeated countries.

There are numerous historical examples of the disintegration of agrarian or semi-industrialized economies under various pressures. Modern industrial societies in this century have shown remarkable endurance and recuperative powers, but these powers have been tested by only two wars. In the First World War the German economy was not attacked directly, and Allied unconditional surrender propaganda during the Second World War seems to have heightened rather than weakened the resistance of the population. The effects of catastrophic military and civilian shock--in the cases of France and Japan--have not been studied quantitatively, and all that can really be said is that highly motivated, tightly controlled societies have on two occasions in this century survived and recovered from very heavy blows. In short, just as it

* The most important of such attempts was Herman Kahn, On Thermonuclear War, Princeton, Princeton University Press, 1960.

** These would include Kahn himself in "Some Comments on Controlled Warfare," in Klaus Knorr, ed., Limited Strategic War, Princeton, Princeton University Press, 1962, pp. 67-68.

was impossible for military planners of the pre-World War I era to use historical analysis to predict the course of a long war with their new quick-firing weapons--although few of them tried to do so--it is impossible now to say much about the behavior of advanced industrial societies under massive nuclear attack. In both cases the basic social and political--as opposed to the basic tactical and lethality--data did or does not really exist.

EFFECTS ON TACTICS

At the tactical level it seems clear that major changes in weapon lethality almost immediately produce some recognizable changes. But the speed of these changes, insofar as any of these factors can be determined historically with any accuracy, has been governed by a wide variety of socio-military-political factors as well as by increases in lethality. A major variable is the "insight" of the responsible political-military leader.

When such a person was a military "genius," such as Gustavus Adolphus, new weapons or new tactical combinations were adopted with considerable speed. Such "geniuses" were usually persons with powerful positions in the political hierarchy and almost always men with considerable combat experience. But even military geniuses were often and properly inhibited by other political and social considerations. Frederick the Great rather clearly saw that the new light infantry tactics might subvert the type of discipline which was necessary in his particular army. He even more clearly hoped to limit his objectives because unlimited efforts by Prussia's potentially stronger rivals might mean Prussia's destruction. There is also no doubt that Napoleon did not carry the French Revolution's military reforms to their logical conclusions because he was too busy administering his Empire and because he dared not place too many burdens on France lest he lose the support of certain key elements in French society. Although it falls beyond the bounds of this study, there seems to be little doubt, if history is any guide, that politically justified fears of the use of any nuclear weapons have hampered and will continue to hamper the exploitation of their inherent lethality at even the tactical level.

Perhaps wartime tactical adaptations at the small unit level may be more rapid in countering new advances in lethality than in exploiting such advances. The assault fire effects of the repeating rifle and the machine gun were not fully exploited tactically until the last stages of the First World War, while

the defensive effects of both weapons were exploited much earlier. It seems equally significant that the British aimed rifle fire which astonished the Germans in 1914 had resulted from their contacts with Boer troops who had also used such fire in similar defensive situations. In any case the flexibility with which small units countered the machine gun, the magazine rifle, and the new quick-firing artillery is quite astonishing when compared with the slowness of the development of the full offensive possibilities of these same weapons.

In the Second World War the adaptability of small units in defense, even though the weapons which they were using had originally been devised for offensive purposes, is again quite impressive. The logic of this factor is simple enough. A well-trained infantry unit of a Western army on the defensive will expend all its resources before retreating or surrendering, while hoping for additional logistic or other support. An equally well-trained unit with an offensive mission will tend not to attack until all of the requirements for such an attack seem to be met.* Since wide distribution of infantry weapons may permit greater exploitation of their lethality than any policy which tries to keep them under central control, it may be important to realize that such wide distribution is by hypothesis also more suitable to the defensive than to the offensive exploitation of these weapons' lethality.

EFFECTS ON ORGANIZATION

Very complex weapon systems have more often than not been adopted in peacetime, partly because of the need for long-range appropriations but more often because they are the result of unhurried reflection upon wartime experience. While peacetime military institutions might be expected to be especially resistant to the resulting organizational changes, linear tactics with the flintlock, mobile artillery, fire direction, the British fire tactics of 1914, the armored division, and perhaps the musket-pike combination were largely peacetime developments.** The list is even longer in naval and air warfare, perhaps because

* Japanese practice in World War II was very different.

** As noted elsewhere, however, full assimilation of new weapons has depended upon battlefield testing.

many of these developments were concentrated in the comparatively long periods of peace between the comparatively short periods of highly concentrated violence of the Age of Technological Innovation since 1850. The armored battleship, the torpedo boat, the destroyer, the submarine, the battle cruiser, and amphibious assault craft were all developed in peacetime, although again the impetus was combat experience. Most of these ships presented new kinds of organizational problems, i.e., those of the torpedo boat or destroyer flotilla in relation to the main battle fleet. The independent bombing force, the fighter-bomber, and the aircraft carrier were wartime developments, but the key ideas of the separate bomber force, the tank-plane team, the fast carrier task force, and vertical envelopment were largely worked out in peacetime.

It is not surprising that the scientific analysis of new ideas and of their long-term organizational implications has often been quite effective in peacetime. Even if the key ideas --of the wolf-pack, American submarine organization in the Pacific, the fleet train, the naval construction battalion, the amphibious assault team, the fast carrier task force, the independent strategic bomber force, the airborne division, etc.--were present in relatively embryonic form at the outbreak of war, they were more likely to be pushed during wartime if they had already won groups of converts knowledgeable enough to develop and defend them against the competing ideas which inevitably crop up in a wartime environment.

Wartime organizational developments may also be subject to political and social inhibitions. Even in primarily defensive situations such unquantifiable inhibitions can override more quantifiable considerations of weapon lethality. One good example is the German failure to develop antitank weapons, tactics, and organizations during the last stages of the First World War because of their supposedly deleterious effects on German morale, although it was already clear that Germany did not have the resources to match the Allies in offensive tank development. It is hard to cite a single instance in which the morale of the experienced infantryman has been affected by developments which promised to increase his defensive capabilities. The Japanese failure to give antisubmarine construction high priorities in the Second World War may also have stemmed partly from a similar fear that such a program would be a damaging public admission of vulnerability. In both cases systematic peacetime consideration of the same problems by professional military men might well have overridden some of these inhibitions.

While the differing pressures of war and peace cannot really be separated in any meaningful fashion, it does seem clear that substantial changes in lethality which involve major organizational changes are more subject to these unquantifiable political inhibitions than those which involve more minor or single service organizational changes. The organization of the German armed services between the two World Wars did not systematically examine or balance out all of the known and clearly possible developments in weapon lethality. It stressed certain developments (the tank-fighter team, the armored division, etc.) rather than others (the independent strategic bombing force, etc.) not because the first developments were inherently more lethal, but because they seemed to be more congruous with a whole complex of other primarily political and quite unquantifiable considerations.

The Nazi party's hold on German opinion was partly premised on the linked and quite "reasonable" ideas that it was not in Britain's national interest to oppose German expansion to the east, that France would not fight well on the offensive, and that Germany had only to kick in the door to bring the whole Stalinist dictatorship tumbling down. When Britain fought and Russia did not collapse, the Germans decided--and again without any scientific study of the potential economic resources of the new Europe --that they had no choice except to stretch their existing concepts of war to the limit.

Though it is beyond our terms of reference, we can remark that the recent record of analyses of competing weapons systems is not wholly encouraging. We should be hard put to defend the idea that the lethality factors inherent in such slogans as "more bang for a buck" have really been overriding in the postwar service reorganizations of a single great power, in the successive force goals set for NATO and other alliances, in the concept of the multilateral force, or even in the current Canadian debate over the size of the unified force which that particular middle power can support. Even in the case of a power which clearly cannot afford everything and which can tailor its forces to a quite specific set of military objectives, nationalistic and international slogans, old service and unit loyalties, and the old problems of French and English Canada are still playing major roles in a set of organizational decisions.

The most important thing is to realize that the language of quantification must not be allowed to hide the continued existence and impact of these traditional unquantifiables, and that this continued existence be realized by the responsible

political, military, and scientific communities. Here it is hard to escape our earlier conclusion that systematic institutionalized analysis must be supported by various general educational programs to foster the understanding and transfer of ideas between the mid-range personnel of the many specialized institutions and professions which are now involved in preparation for war. If the pre-First World War German example has any relevance, this need will grow with the length of any period of great power coexistence.

ON CONTROL SYSTEMS*

There seem to be very few quantitative historical connections to be made between significant increases in weapon lethality and command and control systems. From Assyrian times to the end of the 18th Century the maximum size of individual field armies remained relatively constant at about 60,000 men, or roughly that of the two combined and reinforced Roman consular armies which Hannibal defeated with a somewhat smaller force at Cannae in 216 B.C. This limit was set by logistical factors, rather than by lethality or by command and control factors. Throughout these many centuries command and/or control was exercised by voice, musical, or visual signals of various types and by written or verbal orders carried by runners or by horsed or ship-borne couriers. The limits of visual and sound signaling at sea were even more hampering and were increased in the sailing era by the sailing ship's dependence on wind and weather.

In spite of the invention of the semaphore, this ancient system of command and control began to break down in Napoleon's time, but there is nothing to be gained by further detailed studies of Napoleonic or mid-19th-Century efforts to restore it. It seems sufficient to note that 19th-Century soldiers--such as Du Picq--were well aware of the command, control, and morale problems resulting from the extension of the front made necessary by the development of rapid fire weapons. Sailors were just as acutely aware of the fact that their new fuel needs made the problems of long-range search and command at sea as difficult for steam warships as they had been for sail, in spite of the century's development of the telegraph, the submarine cable, and finally the telephone and radio. Developments in this, as in other fields, were very rapid during the two World Wars; but within the time available for this report it has not

* Also relevant is HERO study "Pre-Alert," November 1963, for the Sandia Corporation.

been possible to attempt to establish quantitative relationships between the expansion of the battle area made necessary by increases in weapon lethality and the resulting strategic spread and tactical depth of present military communications systems.

On this point, however, the military historian will perhaps be forced to admit that his materials are of purely historical interest. Even then, they are probably less illuminating militarily--as in the relationship of the smoke of gunpowder weapons to the growth of musical signalling--than politically, where they certainly throw much light on the problems of early overseas empires. Here, as in other scientific fields, our problems are partly those of seeing which puzzles can best be solved within the limits which are set by the nature of the existing evidence.

The Process of Assimilation of New Weapons
Into Effective Organizations and Tactics
(Annex III-B)

by

Theodore Ropp, et al*

The assimilation of a weapon by an organization has been defined in this study as the adequate reflection of its capabilities in tactics, organization, and doctrine. Adequacy is here measured by the given organization's effectiveness in combat.

When a radically new weapon appears and is first adopted, it is by necessity incongruous with existing weapons and doctrine. This is evidenced in a number of ways: uncertainty and hesitation in coordination of the new weapon; inability to use it consistently, effectively, and flexibly in offensive action, often leading to tactical stalemate; vulnerability of the weapon and of its users to hostile countermeasures; heavy losses incident to the employment of the new weapon, or in attempting to cope with it. From this it is possible to establish the criteria of assimilation as follows:

- a. Confident employment of the weapon in accordance with a doctrine which assures its coordination with other weapons in a manner compatible with the characteristics of each.
- b. Consistently effective, flexible use of the weapon in offensive warfare, permitting full employment of the advantages of superior leadership and/or superior resources.
- c. A capability of dealing effectively with anticipated and unanticipated countermeasures.

* A basic study by Professor Ropp was abridged and modified by the HERO Staff.

d. A sharp decline in casualties when employing the weapon, usually combined with a capability for inflicting disproportionately heavy losses on the enemy.

If the enemy has not assimilated the significant increase in lethality the organization that has will be notably more effective than the enemy. If the enemy has also assimilated it, then the outcome of engagements will be traceable to command factors, inadequacy of logistical support, or chance. If the enemy has assimilated the advance, and the force considered has not, then more engagements will be lost than can be explained by failure in command, logistical support, or chance.

There are many points of resemblance between significant advances in the natural sciences and significant increases in the lethality of weapons. Both have been coming at shorter and shorter intervals in modern times, and advances in lethality have generally flowed directly from those in the natural sciences. In earlier days both reflected the effort and inspiration of an individual, while in modern times they are more apt to be the product of groups of men working in institutions. Both the advances and the increases are revolutionary, so that neither science nor the practice of war is the same after their appearance. Both are likely to meet with varying degrees of resistance from proponents of the established order. And, both the natural sciences and war were governed for centuries by tradition and the teachings of authority; it is only in comparatively recent times that both have come to use the scientific method, that is, systematic combination and use of hypothesis, data-gathering, analysis, and testing.

If the resemblance be accepted for the purposes of this discussion, then a line of analysis which has fitted known data about the significant advances in the natural sciences may also prove illuminating and productive when applied to the military. The line of analysis is based on that developed in 1962 by Professor Thomas S. Kuhn of the University of Chicago.* The particular merit of Professor Kuhn's analysis is that it has proved helpful in explaining the sudden discontinuities and differing rates of progress that are observable in the natural sciences. It is at least arguable that a sudden discontinuity in science is very similar to a sharp jump in lethality. Each is the result of a revolutionary new idea. Each must in turn be assimilated. Therefore, what has proved helpful in explaining what happened in science may

* In The Nature of Scientific Revolution, Chicago, 1962.

be useful in reaching a better understanding of what has been happening in the military.

According to Professor Kuhn's analysis, any body of organized knowledge, i.e., any natural science, produces a pattern of thinking, or "model," which influences the ways in which people work in that field. This tends to suggest the problems to be investigated in that field as well as the methods to be used in solving them. Using these methods, the thinker finds problems solvable. Because of the existence of this pattern of thought, however, some real problems are not apparent to the ordinary worker. Thus, until the laws of heredity in plants were generally accepted, from about 1900 on, scientists did not recognize the problems related to the transmitting of dominant and recessive traits, for their very existence was not known. It may take decades--or longer--for a new thought alien to the currently accepted pattern of thinking to become assimilable.

For example, Gregor Mendel published his discoveries in genetics in 1866. They were circulated to all the principal libraries of Europe and North America. But they were too revolutionary for the time, and contemporary scientists ignored them completely. In 1900, six years after Mendel's death, three scientists independently duplicated his discoveries. Searching the literature, they found that Mendel had published both the same experimental data and their conclusions from it 34 years before. The world was then ready to accept his teachings, and, thanks to the generosity and integrity of the three men, Mendel was hailed as founder of a new and revolutionary science.

While there are many points in common between the intellectual content of problems faced by the soldier and the scientist, the soldier works under handicaps from which in most countries the scientist is free. In every nation, the soldier is part of the state organization because both war and preparation for war are political acts. What the soldier does and says, and the means at his disposal are of keen interest to the executive and the legislative in democratic states and to the ruling clique in dictatorships. Much of his attention in the course of his career is given to the maintenance and safeguarding of the state property of which he is custodian. Only in totalitarian states does the government take a corresponding interest in what scientists do, say, and think, and in the Soviet Union at least among them these controls may be proving impractical.

A second handicap is that in peacetime (and in modern times the Great Powers have been usually at peace) the soldier finds it difficult to test his hypotheses and his devices. Until very recent years, he had only maneuvers, test ranges, and service schools. A few years ago, the United States began to experiment with a test center that would duplicate as much as possible of what happens in combat. None of these, however, could have the weight and acceptability of a well-done laboratory experiment.

The soldier is thus under very real constraints, and the tests he can make in peacetime have been so limited and partial that they can be characterized as weak. The authoritative and critical test for the soldier remains war, and it is war that indicates whether or not the model the soldier is applying is valid.

To return to Professor Kuhn's analysis. Men take the current model or way of thinking for granted, assuming that it fits the world as it exists and that by following its lead they will get the results they seek. They do not question the model, although they may not be certain that they are using the right approach to problems. In order for a model to change, that is for a significant advance in science or in weapons to be assimilated, two conditions must be satisfied. In the first place, a problem must refuse to yield when the currently accepted methods are applied to it. Second, there must be an alternative model to substitute for the old one.

An example of this from military experience may be found in World War I. In 1914-1916 the current pattern of British military thought did not suggest a workable solution to the problem of how to break through the German trenches, barbed wire, and machine guns. It was inventive juniors and outsiders who were not bound by the current pattern of thought who created the tank. The implications of the tank suggested a new line of thinking, or a new model, which for brevity might be called a primitive armored warfare. Only then did the British military community give up the old model and begin to work into something new.

The replacement of a new model by an old is usually not a smooth, easy process. For one thing, new models need new language which sometimes is not readily intelligible to those accustomed to thinking in old ways. Another problem is that advocates of the new model cannot demonstrate a series of successes. For these reasons it is sometimes necessary to await the passing of a generation from authority in order for a new model to gain acceptance.

Throughout history there have been four basic preconditions for assimilation of new weapons or ideas into military systems:

a. An imaginative, knowledgeable leadership, military and civilian, supported by extensive knowledge of, and competence in, the nature and background of the existing military system.

b. Effective coordination of the nation's economic, technological-scientific, and military resources.

c. A reasoned, analytic capability assuring sound judgment in the processes of innovation and adaptation.

d. Opportunity for battlefield experimentation as a basis for evaluation and analysis.

We shall return to the first and last of the preconditions later. For the moment it is relevant to suggest how available 20th-Century institutional arrangements and policies can best foster the formulation of models, the awareness of their having been tested or their susceptibility to test, the capability of testing the validity of models, and last of all the capability of formulating alternatives. These arrangements and policies are:

1. The existence of industrial or developmental research institutions, basic research institutions, military general and technical staffs and their supporting research institutions, together with administrative arrangements for linking these with each other and with the government.

2. Conduct of research, development and testing activities by these bodies through methods and procedures sufficiently common and familiar that their personnel can communicate, can be mutually supporting, and can evaluate one another's results.*

* It is not commonly realized how recent it is for the great universities to take an interest in any sort of science and so be able to offer help or even be able to communicate with the armed services as the latter worked with problems of weapon development and assimilation. Thus not until the reforms of 1877 were a portion of Oxford's revenues allocated to work in the natural sciences. Twenty-three years later, in

3. Direction of the efforts of these institutions--in all matters relating to weaponry and doctrine--toward a common and clearly defined goal.

When these arrangements and policies were absent, as they were until well along in the 19th Century, progress and change as regards the military was most commonly the work of a man of commanding intellect who was also at the head of the state, for example, Philip of Macedon, Edward I of England, Gustavus Adolphus, and Frederick the Great. In some fewer instances change came about by somewhat random invention at the tactical level, as in the case of the assimilation of gunpowder and hand-guns over an extremely long period of time. Given the number of heads of state since the days of Philip of Macedon, compared with the much smaller number of heads of state who have ranked militarily with him or his son, or with Napoleon, it seems that the probability of such men appearing at any time is low; thus progress resulting from their presence must be slow and spasmodic. Random invention at the tactical level is even less productive because of the organizational problems inventors there face in trying to convince colleagues and superiors.

Assimilation of significant increases in lethality in the present day can be greatly expedited and facilitated by attention to the arrangements suggested above. Better linkage between institutions, a complete set of such institutions or sub-agencies able to discharge appropriate functions whatever the organizational set-up may be, agreement on goals, agreement on research method, ability to communicate, ability to move personnel freely from one institution to the other would improve the ability of an army to formulate a model, to perceive the results of its having been tested, and judge it against these results. They would also seem likely to improve the probability of having alternative models under consideration should the currently accepted model prove unable to pass its tests.

Let us now return to consider the first of the preconditions of assimilation, which can be summarized as the need for imaginative, competent, knowledgeable leadership. For reasons pointed out above, we cannot rely upon chance or divine providence to

1900, only 21 of 142 college instructors were scientists. In that same year, less than 10% of the students majored in science. The Harvard graduate school of arts and sciences was founded in 1872.

assure this. Yet there are indications that the development of imaginative, competent, knowledgeable military leadership can be assured, or at least enhanced, by an intensive effort to analyze the causes and essential nature of military creativity. It is beyond the scope of this study to undertake such analysis, or to develop the achievable means for stimulating and enhancing such creativity and for elimination or suppression of the inhibitions to such creativity. But it can and should be done.

As to the fourth precondition (opportunity for battlefield experimentation) it is not yet clear whether our new methods of peacetime testing and experimentation--through sophisticated wargames, computerized evaluations, and the like--are in fact sufficiently realistic to provide adequate substitutes for battlefield experimentation. There is good reason to believe that, at present, they are not.

More useful, perhaps are attempts to recreate in peacetime the test of combat under physical conditions that simulate war as closely as possible and that also permit study. We have reason to believe that such attempts, as at the Combat Development Experimental Center at Fort Ord, have been useful, but still inherently lack the physical and psychological elements of conflict, risk, and destructiveness which are the essential elements of combat, and without which there can be no real combat trial.

It has recently been brought to our attention, however, that the Institute for Defense Analyses has recently successfully investigated engineering methods of integrating two previously unrelated technological testing methods which might permit actual recreation of combat conditions for testing weapons and tactics, at least on a limited scale. This investigation, as we understand it, has been the marrying of the most recent methods of individual television surveillance and of the remote handling of radioactive materials to permit actual projection through "telefactor" of an individual's intelligence and reactions to control of objects in space through television and telemetry. The production of a workable prototype is anticipated within two years.* If the system works as envisaged (and there appears to be no scientific or engineering reason why it cannot),

* A report on this matter can be expected from the Institute for Defense Analyses shortly after November 1, 1964. Contact at IDA is Mr. William Bradley, Deputy Director of Research, who instigated an intensive investigation of this matter in a 1964 IDA Summer Study.

it could be applied to the testing under full combat conditions of opposed weapons or weapon systems, tank against tank or anti-tank weapon, aircraft against other aircraft or anti-aircraft defenses, etc. Even broader applications may soon be possible, to permit for the first time in history, actual armed conflict between human opponents, with no limitations on effects of weapons without danger to human life. The significance of this to tactical development is obvious, in light of the preceding discussion. The possible combat application of the "telefactor" concept is fascinating, but beyond the scope of this study.

Impact of Imaginative Thinking
on Military Organization and Tactics
(Annex III-C)

by

Riley Sunderland
and
T. N. Dupuy

Given the definition of weapon lethality as an inherent capability of a physical object it would seem that organization and tactics could act either to exploit or to inhibit that capability. For purposes of this study, the effectiveness of a weapon is the measure of the extent to which this inherent capability is exploited.

The relevant changes in organization and tactics would seem to be (1) those which exploited more of the inherent lethality of the weapon than had been the case prior to a change; or (2) which solved problems which had precluded earlier effective use of the weapon in combat. These changes could be in the distribution and control of the weapon, in its relationship to other weapons, or in the technique of employment by its user or its crew. They are thus, by definition, changes in the use of a weapon rather than in its structure or ammunition. However, we shall note that there are frequently alternating changes in doctrine and in structure, during the process of assimilation or of development either of weapons or of doctrinal systems.

Analysis will proceed by noting some of the important doctrinal changes in the basic historical studies and then considering what they offer on the problem of the interrelationship of organization, tactics, and weapon effectiveness.

Military tactics, organization, and doctrine are much more likely to be affected by new ideas, new concepts of employing men and weapons, than they are by the appearance of new weapons

alone. More often than not it has been the application of sound, imaginative thinking to existing weapons which has caused the great developments in military affairs, and which has affected international relations. Even the new weapons which were the basis of the revolutionary Macedonian and Roman tactical systems, were in reality only modifications of existing weapons.

The Roman short sword shows clearly how ideas can affect a weapon. To thrust rather than to cut or slash, given the facts of human anatomy, was a sharp increase in lethality. Instead of a deep cut that may or may not become infected and which the shoulder bone structure often kept from the vital organs there was almost the certainty of some form of infection, probably massive, probably fatal. Since earliest uses of the sword suggest that it is in origin a sort of edged club, cutting or hacking would seem to be the natural stroke, while thrusting was the result of much reflection on combat experience. Then, considering the space a man needs to swing a sword against that he needs to thrust, more men thrusting may be put in the same length of front than men swinging. One thus multiplies the advantages of the more effective technique, and this the legion did.

The importance of new or imaginative ideas in military affairs--as opposed simply to new things--can best be gauged by the fact that it has almost invariably been new ideas which have permitted inferior military forces to overcome forces that were larger and/or better equipped. Hannibal was the best example of this in antiquity. He had no new weapons (his elephants were relatively ineffective against the Romans), his troops were inferior in quality, training, and weapons. His amazing string of successes was due to his ability to use combined arms, to improvise both strategically and tactically, and in particular to his focus on maneuver. He has rightly been called "the father of strategy," and his imaginative thinking stimulated the development of the modern Schlieffen Plan.

The even more astounding successes of Jenghiz Khan were achieved in almost every instance against forces that were numerically superior and which had similar or comparable weapons. Unlike Hannibal, Jenghiz invariably did enjoy superiority in training and discipline, but this alone could not explain the extent or nature of his conquests. The reason was an incomparable genius for developing new ideas in organization and administration, combined with the same kind of imaginative tactical and strategical genius which Hannibal had displayed. New ideas, unexpected and unknown to his opponents, were the reasons for success.

Equally relevant, though a different kind of example, is the way in which the Swiss used the long pike--almost identical to the Macedonian sarissa--to dominate European battlefields for a century. Combining tactical mobility, speed of movement, surprise, and an unfailing offensive spirit, the unarmored Swiss, in dense columns not unlike the phalanx, charged at the run to overwhelm heavily armored knights on horse or on foot, as well as all other varieties of medieval infantry. They were for a while able to maintain an ascendancy over early gunpowder weapons, as well, dashing through the beaten zones before enemy fire could do them serious harm, or else attacking by surprise from an unexpected direction before the clumsy existing systems of command and control could respond.

There is, of course, no better example of the impact of ideas on existing weapons than the military system developed by Gustavus Adolphus. As we have seen, he not only modified weapons drastically, he combined them into a military system which, to some extent, has lasted right to our own day.

Another example is the adaptation of the flintlock musket to linear tactics. Although it could fire five times a minute as against the much slower rate even of the improved matchlock musket, the single flintlock's lethality was limited by its low accuracy which offset its rate of fire. Extending the earlier massed formations into a line of two or three ranks meant that fire from any one, two, or three ranks would cover the target area with a mass of fire, so that the respective inaccuracies cancelled out. At mid-range, one flintlock was not very dangerous but many flintlocks were deadly, and the impact of a volley from a line of muskets could be decisive physically and morally.

The Prussians then provided an additional refinement to the flintlock. King Frederick William I sponsored the development of an iron ramrod which, when exploited by training, sharply increased the rate of fire of the Prussian infantry without in any way changing the weapon or its method of operation. Prussian training, discipline, and superior firepower--as well as his own imaginative genius--were then exploited by Frederick William's son, Frederick the Great, to make Prussia, then only a small German state, a great power and to permanently change the balance of power in Europe.

Napoleon introduced neither a new weapon nor a new tactical system. Although he was an excellent tactician, his principal impact on warfare was by injecting new and imaginative ideas into

strategy and grand strategy. One indication of the potential and actual lethality of ideas can be obtained from the comment of one of his enemies (Blucher, though the statement has also been attributed to Wellington), that Napoleon's mere presence in a battle or campaign was worth at least 40,000 men. The strategic concepts of Napoleon, novel at the time, are now commonplace due to the writings of Jomini and Clausewitz.

More recently we have seen new ideas adapted to relatively new weapons, during the process of assimilation to bring that process to a climax. Both tank and fighter aircraft are examples. In the case of the fighter, fitting bombs to it so that it can attack ground troops now seems obvious, but the concept was a British idea of World War I, and so far from obvious that contemporary German practice was to use light bombers, i.e., two-seaters. Use of the dive-bomber, previously only the equipment of as-yet untried Japanese and American naval air squadrons, for work against point ground targets, because of its accuracy fully exploited the lethality of aerial bombardment. This was a German innovation, sensational until countered.

New ideas, as demonstrated in novel tactics and doctrine, can also give the introducing power the advantage of surprise. Twice within the lifetime of men now living the German Army has scored stunning tactical surprises over its opponents, in 1918 and again in 1940, yet in neither case did it use new weapons. Every item in the German arsenal was familiar, yet use of these weapons came as a great surprise.*

The above discussion permits us to develop a number of observations and interesting hypotheses about ideas that more fully exploited the inherent capabilities of weapons.

The first observation is that--with one possible exception**--all ideas are of military origin.

* Another example of imagination--whereby "rhino horns" were fitted to tanks to rip through the hedgerows of Normandy--is discussed by R. E. Dupuy in Men of West Point, Sloane, NY, 1951, pp. 273,274.

** Changes in the artillery carriage to permit elevation and traverse may have been made by civilian technicians. Given the very different nature of society and of the military in the late Middle Ages from what it is today, an attempt to fix social origins in this case may not be too meaningful.

It is interesting to note that the actual adoption of changes discussed above have come both in peacetime and in war. For instance the ideas we have noted relating to the dive-bomber, the armored division, mobile artillery, fire direction, British musketry, and linear tactics with the flintlock were all adopted in peacetime--though all were based on evaluation of combat experience. The combination of musket, pike, and countermarch may have originated in peacetime, and this may also be true of indirect fire. Ideas of clearly wartime development are: fighter-bomber, scientific gunnery,* tank tactics, assault fire, and battle drill. The balance inclines toward peacetime.

If it is accepted that up to 1953 the military have originated most ideas for the fuller use of weapons, and usually did so in peacetime, how long after the introduction of the weapon did these ideas follow? This is an area, of course, in which precision is impossible and the danger of fitting facts to preconceptions apparent. This is discussed at some length in Annex III-B, in the consideration of problems of assimilation. It would appear, however, that further research and thought given to this subject might be rewarding in a search for underlying principles regarding innovation and creativity.

For our purposes, at this time, however, the important thing to note is that over the course of history ideas regarding the employment of weapons have been far more important than the weapons themselves--whether these were new weapons or those that were old and familiar. We were rudely reminded of this by the Chinese Communists in Korea, who had no air support, little armor, weak artillery, and were generally backward in weapons and equipment. Yet through a combination of initiative, determination, and imaginative exploitation of our previously unrecognized weaknesses, they inflicted some sharp defeats on American forces. In different ways, the same lesson has been taught to the French and ourselves in Vietnam, where the guerrillas have so deprecated weapons that they have used their enemies--us--as an arsenal.

History still shows--as it has time after time--that imagination in weapons employment will make up for clearly discernible qualitative and quantitative inferiority in manpower, or weaponry, or both.

* In fullest form, by the French particularly in World War I. This is a debatable point, however, particularly since the most significant modern artillery development--the American fire direction system--was a peacetime development, as noted above.

Effect of Tactics on Development of Weapons (Annex III-D)

by

Wlodzimierz Onacewicz

The evolution of tactics has usually been stimulated by the development of new weapons which both induced the military to seek the best way to use the weapons, and at the same time forced them to look for countermeasures to protect their own forces from the lethal effects of enemy employment. However, there have been a few cases in which this order was reversed and when weapons were invented, or modified, to help the realization of preconceived tactics.

The sarissa, for instance, was modified from the standard short pike to serve the new offensive tactics of Philip II of Macedonia; many centuries later the long pike was re-adopted for the Swiss phalanx, in each case for the purpose of outranging the weapons of the enemy. For another, Gustavus Adolphus developed a whole system of weapons to fit his tactics and to enable his small army to defeat more numerous opponents. In modern times the tank was invented in 1915-1916 to enable stalemated Allied armies to break through the German fortified front, and the proximity fuze was invented in World War II as a means whereby artillery could cope more effectively with dug-in troops by using air bursts that would surprise their target.

SARISSA

Knowing the weak points of the Greek phalanx--its rigid order, slowness, and vulnerability on the flanks--Philip decided to defeat the Greeks by the combination of strong infantry and mobile cavalry. He intended that his infantry phalanx should serve as base for maneuver, and he attached to it highly mobile cavalry wings, which could attack the flanks and the rear of the Greek phalanx.

For his purpose, Philip created a standing army, divided into battalions (256 men strong) which made it more flexible, and improved the quality of the infantry by training. But he also armed the members of the 16-man deep phalanx with the sarissa, a 14-foot long pike. The sarissa, which outranged the Greek pike by several feet, was intended to make his center invulnerable to the attacks of the contemporary Greek phalanx.

The long sarissa did not improve the mobility of the Macedonian phalanx. Philip, however, was able to achieve improved mobility by discipline and training in a regular army. His son, Alexander, used the previously unwieldy phalanx, with its long pikes, as an instrument of offensive warfare in powerful frontal attacks, while his cavalry was attacking the enemy's flank or flanks.

SWISS PIKE

The Swiss pike, which was about 20 feet long, and thus was even longer than the sarissa, was developed to meet the need of the Swiss mountaineers for a long deadly weapon which, combined with tactical mobility, would permit unarmored foot soldiers to cope successfully with the heavy armored cavalry of the Hapsburgs. The long pike, unwieldy in hand-to-hand fight, was combined with the halberd, a shorter (about 8 feet) but equally deadly pike terminated with a heavy axe backed by a strong hook.

With these pikes the Swiss heavy columns, or phalanxes, were irresistible in attack and impenetrable in defense. The halberdiers, placed in the center of the phalanx, dealt with any enemy who penetrated the front ranks of pikemen, or disposed of enemies bypassed by the front ranks.

The Swiss phalanx, an essentially offensive weapon system, highly mobile and able to change direction quickly, not only defended Switzerland against subjugation by Austria and Burgundy, but became for more than a century (from the end of the 14th Century and to the second quarter of the 16th Century) the most effective single arm on the battlefields of Europe.

THE WEAPON SYSTEM OF GUSTAVUS ADOLPHUS

Gustavus Adolphus based his tactics on mobility and the combined action of infantry, cavalry, and artillery, and on the

maximum use of firepower in both attack and defense, although the attack was his usual mode of operation. The important role which he ascribed to firepower induced him to introduce a number of significant changes and improvements in contemporary firearms.

In order to boost the offensive power of the infantry, he increased its firepower, using a lighter musket and increasing the proportion of musketeers to pikemen (72 musketeers to 53 pikemen in a company). The mission of the musketeers was to defend the pikemen by fire against charges of heavy cavalry, and to prepare by fire the attack of the pikemen who constituted the shock arm of the infantry. To implement this concept, he used the lighter musket to increase the tactical mobility of the musketeers, standardized the caliber and powder charge, and introduced paper cartridges to increase the rate of fire.

The most important innovation of Gustavus Adolphus, however, and one which considerably increased the offensive power of his army, was the introduction of a new infantry cannon, the regimental gun, sufficiently mobile to accompany the attacking infantry. This was an iron four-pounder, four feet long, and weighing 625 pounds with carriage.

Infantry and cavalry (also with regimental guns) were used by Gustavus in close combination with field artillery. In order to increase the mobility of his artillery and its rate of fire, Gustavus Adolphus shortened the barrels of the guns, made the carriages lighter, and introduced the cartridge. He then used artillery to break up the enemy's squares* by concentrated fire from a distance.

The great superiority of Swedish tactics resulted from the flexibility and mobility of their formations, combined with the skillful use of increased firepower, all exploited to the maximum by the creator of the combination. After his death, the system created by Gustavus Adolphus was imitated by all European armies and was the foundation of their tactics for the next two centuries.

* The "Spanish square." A massive block of pikemen and musketeers; made obsolete by these new Swedish tactics.

TANK

The tank was developed by the British during World War I as a weapon for the rupture of the stabilized Western Front, a continuous line of entrenchments, protected by barbed wire and concealed machine guns. Allied infantry, even though supported by formidable artillery, proved unable to break through such a strongly fortified front.

The first use of the tanks in September 1916, in the second battle of the Somme, was a mistake and a failure. At Cambrai a year later the tanks successfully accomplished their mission of a rupture of the front. This tank success could have led to a decisive British victory, had the British High Command prepared sufficient reserves for the exploitation of the breakthrough, or if the tanks had been more developed mechanically and able to continue in action longer, and help exploit their own breakthrough.

The full exploitation of the capabilities of tanks--after considerable mechanical and armorment improvements--came in World War II, where the Germans grouped them in armored divisions, operating in combination with the air force, and employed as a strategic arm.

PROXIMITY FUZE

One of the great inventions of World War II was the proximity fuze. Its development was prompted in the United States by the realization of the relative inefficiency of the standard time fuze used by artillery against infantry and aircraft alike. The invention of radar provided a means for rectifying this situation.

Prior to this mechanical time fuzes had been used for anti-aircraft shells. These were set automatically by computers linked directly to optical or radar sensor devices. Theoretically these should explode the shell at the moment when the aircraft came within effective range of the blast and flying fragments. In practice, however, the projectile velocity was such that even the slightest deviation of the fuze from perfection, even of a fraction of a second, could cause the burst to occur anywhere along several hundred feet of trajectory, even when the projectile was aimed perfectly.

In land operations similar time fuzes were employed to obtain air bursts over enemy entrenchments. The technique of adjusting such fire was complicated and difficult for observers, even under peacetime circumstances. In practice timed fire was relatively ineffective, even without the slight deviations inevitable in the time of burst.

The problem, as it was posed, therefore, consisted in developing a fuze that would operate not by time, but by the proximity of the target. The fuze must function when passing within effective fragmentation range of the target, in any weather, and whether in daylight or dark. It also must be provided with a self-destructive device to prevent injury of friendly troops, civilians, and valuable equipment, in case an aerial target was missed.

The US Navy had been considering the possibility of devising an influence fuze based on the principle of radar. After the establishment of the National Defense Research Committee (in June 1940), this project was the first that the Navy asked NDRC to study. The proximity fuze evolved from collaboration of many people: the NDRC and its contractors worked out the basic electronic features, ballistic and fuze experts of the Ordnance Department provided the guiding data to adapt the fuze to existing types of ammunition; production engineers adapted the design of the fuze so that it could be manufactured by assembly-line methods. Thanks to radar, a problem of extreme complexity had been solved.

The fuze contained a miniature radar set, broadcasting a continuous signal that was reflected back to the fuze as it approached the target. The fuze was triggered by reflection from the ground, from an aerial object, or from a target projecting above the surface of ground or sea. This delicate mechanism had sufficient ruggedness to withstand the rotational and setback forces of conventional artillery. It was manufactured for bombs, rockets, antiaircraft, field artillery shells, and by the end of the war, for 81mm mortars. And, in a great triumph of production engineering, this tiny, complex mechanism could be mass produced by assembly-line methods. Production began in the latter part of 1942, and it became available in January 1943.

For the first 18 months the use of the proximity fuze was restricted to the US and British Navies, because of the danger that an enemy might salvage enough pieces to discover the design of the new fuze. The first VT fuzes (from VT, the code

designation of the proximity fuze) used in combat were fired in January 1943 by USS Helena to bring down a Japanese plane.

In the summer of 1944, Army antiaircraft batteries in England, fighting the German "buzz" bombs (V-1), used proximity fuzes with good effect. During the last four weeks of the V-1 bombings, the effectiveness of the American antiaircraft artillery mounted steadily and V-1 destructions rose from 24% to 79%. The British credited the proximity fuze, together with American antiaircraft artillery, radar, and fire control, with saving London from the buzz bomb.

Antiaircraft proximity fuzes were first used on the continent against the German air force on the first day of the battle of the Bulge (December 16, 1944). This use continued until the end of the war.

The proximity fuze also proved to be quite lethal against enemy ground forces. Two American Corps (VIII and V) facing the German attack in the Ardennes were given 3,000 VT fuzes, which they used for the first time on December 18, 1944. These fuzes were extremely effective, but apparently not in sufficient numbers to cause the Germans to realize initially that a new weapon was being employed.

The VT fuze was employed not only in artillery shells, but also in rockets and bombs. On Luzon by the end of May 1945 all 105mm howitzer batteries were using proximity fuzes. Proximity fuzes in bombs to produce air bursts were employed for the first time in February 1945 when the Seventh Air Force dropped proximity-fuzed fragmentation, general purpose, and incendiary bombs at Iwo Jima. The largest bomb for which the VT fuze was adopted was the 2,000-pound general purpose AN-M66.

Effects of Changes in Organization and Tactics
on Effectiveness of Existing Weapons
(Annex III-E)

by

Samuel R. Shaw

In general weapons have governed tactics and organizations have been designed to facilitate the employment of the tactics. In most cases, particularly after the development of firearms for both infantry and artillery, a common pattern has been followed. The major increase in the effectiveness of existing weapons has come when the leadership has conceived the new tactics which available weapons (including modifications) permit them to employ, and then placed the troops with their weapons in organizations suitable for the tactics.

In most cases the leadership has included in their tactical conception the development of a doctrine of some kind, forming a logical coordination of the elements involved. This doctrine has been more than something involving only major commanders. It has extended to details of training, small unit methods, and even individual conduct.

There is little evidence that changes in effectiveness of any given weapon, or even the introduction of a new weapon, gave any significant advances in over-all effectiveness of an army until a new conception arrived. In the new conception, the improved or new weapons were only a part of the rearrangement.

All of the significant changes involved the processes mentioned above. They all involve a tactical conception aimed at producing the maximum combined effect of all the weapons in a decisive area. They all included an increased degree of mobility on the immediate battlefield for one or more of the weapons involved. Except for the German infiltration methods of 1918, they all involved a new degree of mobility in the

approach to battle, and in the continuation of action after the success of any particular engagement.

The 1918 Germans lacked an element which was included in all the other successful new conceptions. The tactical doctrine for combat was not accompanied by logistical methods which could continue the advance beyond its initial success.

The British use of the tank in World War I also illustrates this point. The British command had not completed an intellectual development of either the tactical measures or organizational support which could exploit a tank breakthrough of the hardened shell of German defenses. The British had not foreseen the necessity for infantry to closely follow the tank successes in order to combine their effects and to hold on to the ground gained, nor had they foreseen the necessity to be prepared to rush through the area of rupture with fresh troops not disorganized by the previous period of combat.

The methods of Gustavus Adolphus and Napoleon, the German methods of 1870, the German infiltration team of 1918, the German infantry-armor-dive-bomber team of 1940, and the American amphibious methods of World War II, all are examples of significant advances in battlefield effectiveness which involved the processes discussed above.

The use of the machine gun in World War I illustrates the process. At the outset neither side appears to have formed a new tactical conception, offensive or defensive, accompanying the introduction of this relatively new weapon. There was no real change in basic organizations. Machine-gun units were merely stuck on to existing infantry units. Certainly neither the Germans nor the French, with their focus of attention on attack methods unchanged by the addition of the machine gun, were prepared for its dominating effect in defense.

When the defensive employment of machine guns was complemented by the tactical siting of quantities of barbed wire, the resulting battlefield stalemate took both sides by surprise. The machine gun when placed in an organization designed to achieve a combination of its fires with other weapons, in tactics of maneuver based on these combining of fires, became an essential part of the infiltration team.

The intellectual development of the new combinations of weapons and tactics was based upon a prior determination or assumption of the theater of action and the nature of at least the most likely opponent. In the case of European armies

this required no great feat of imagination since the nature of the theater and the probable enemy was clearly evident. The adaptation in 1940 of the German armor-infantry-dive-bomber team to the special conditions of desert war was an imaginative projection to a new theater. The more or less parallel British development probably came easier since most of the commanders and troops involved had had the prior experience of the early actions in the Near East.

The American amphibious doctrine had its origin in just such an intellectual appreciation of its strategic necessity for the United States. Much of its equipment requirements, such as the amphibious vehicle, were based upon an analysis of the probable theater, the Pacific, with its reef-fringed atolls. The adoption of the helicopter-borne landing methods, and the Fleet Marine Force reorganizations of 1948 and 1958 to advance these methods, were all accompanied by such an analysis of prospective theaters and enemies. Generally, the analysis of prospective amphibious operational areas and opponents is a somewhat simpler affair than for continental operations. The immediate landing areas of most shorelines have a considerable degree of similarity, and the defensive organization of landing areas follows similar patterns regardless of fundamental differences in the units, weapons and tactics of various countries.

It may be noted that the US Army has been faced with a most difficult conceptual task since 1945. Our world-wide commitments give us possible large scale actions in several theaters whose natures are vastly different, and where the probable opponents are also greatly different. It is apparent that the US Army has been organized, trained, and equipped primarily for action in western Europe. The focus of attention on combat in this area, heavily laced with good highways and railroads, has been the major influence on the Army's organization and equipment.

This factor certainly had its effect on Army operations in Korea. The difficulties in adapting to the conditions in Viet Nam, complicated by the fact that this sophisticated arrangement is being grafted onto a people unaccustomed to it, in an area little suited to it, are apparent.

This conceptual problem is exemplified by the short life of the pentagonal division. It was an organizational arrangement, and weapons were arbitrarily selected without the elaboration of the tactics with which the organization would use its weapons. The lack of a thought-out tactical doctrine led to a lack of sufficient command and control arrangements beneath Division

headquarters. Hence these arrangements had to be improvised for each tactical scheme. The adoption of an organizational scheme before the tactical conceptions were thought out, was soon seen as a cart before the horse arrangement. It did not last long.

The Allied lack of a doctrine combining the fire of aircraft with the fire and maneuver of ground units was one of the great defects in Allied conduct of the European campaign. This was true both in the sense of the action of regiments, divisions, and corps, but also in the operation of Armies and Army Groups. The Strategic Bombing Survey notes that the secondary air campaign against transportation was the decisive air campaign. It goes on to say that this was not coordinated with the ground campaign, even though requested by the ground commanders. The Allies had failed to see what the Germans had demonstrated of the possibilities in such actions. They did not realize what could have been done with the great weight of aerial munitions deliverable by the Allied air fleets.

The use of close air support methods for units in contact, coupled with the use of the Allied heavy bomber fleets against the communication routes of German reserves would have enormously quickened the Allied advance. Particularly if the air plan had been properly coordinated so that, while German movement was largely denied, the French and German rail systems could have been used by the Allies with a minimum of repair time.

The existence of a well-understood, carefully thought-out doctrine for combining the effect of all weapons in such a way as to enhance the speed of advance has the effect of a large increase in the shock of the action. It may be thought of in the sense of the formula for momentum where $M = \frac{1}{2}mv^2$. The longer the momentum is maintained the greater the effects of the shock. It is a pity that the Allied air fleets were not so coordinated with the ground attack that this exponential effect could have made use of all available weapons.

In another way the existence of such a doctrine has great effect. It makes up for damage to the control systems, or circumstances in which communications do not meet the demands. For instance, in the Gallipoli landing, the British force that landed at Y Beach got ashore unopposed. Communications failed. It milled about and the next morning re-embarked and returned to its ship without accomplishing a thing. An adequate doctrine for landing would have caused it to take action which might have turned the landing into a success.

The significant increases in effectiveness have all come from military sources. It is readily apparent why this is so. Regardless of who may have invented or perfected a weapon, significant increases in effectiveness have not come until it, and other weapons and equipment, have been combined into a new coherent conception of action on the battlefield. Obviously such a conception, embodying as it must a large amount of the intimate details of military life and action, starting at the details of individual conduct and training, can only come from within the military profession itself.

This aspect of weapon development is overlooked nowadays with the emphasis on cost effectiveness. Weapons are retained or removed from the approved list of developments because of factors which have no relation to their ultimate place in military organization or tactics.

The cost in dollars is significant. It is certainly a factor which must be taken into account, and traditionally has been, by the military as well as their superiors in government. This study should show, among other things, that the actual effectiveness (or battlefield effectiveness) of a given weapon or piece of equipment can be estimated approximately only when it is placed in context within the entire set of circumstances involving its employment.

Organization for Development of New

or Improved Weapons
(Annex III-F)

by

Edward S. Gilfillan, Jr.

Two closely related problems are here considered; one is to design an organization for the development of a new weapon and the other to design an organization for improvement in the lethality of an old weapon. Much the same definitions and mathematical formulations are applicable to both.

First take the case of enhancement of the lethality of an old weapon. It is postulated that

$$1) \quad \frac{L}{L_0} = \log\left(1 + \frac{ku}{w}\right)$$

where L and L_0 are the absolute lethalties before and after enhancement, u is the effort necessary (the unit of u is the dollar but a unit of u will always require more, and ordinarily much more, than a dollar of allocated funds), w is the weight (in tons) of the weapon, and k is a constant to be determined from historical data.

The case of the development of a new weapon is formally the same, with only the meaning of the L_0 different. In this case L_0 is the lethality of the weapon as assembled from existing components before any development work.

Formula 1) is merely a quantitative version of the Law of Diminishing Returns.

To use formula 1) it is first necessary to postulate a relationship between the "effort," " u ," and the funds, " v ," allocated. This relationship depends on the size of the

developmental organization, the time it has been in existence, and the time available for making the development. The relationship postulated is

$$2) \quad u = f_0 w e^{-cs} \left(1 + \frac{a}{v}\right)^{-1} \left(1 + \frac{bn}{w}\right)^{-1}$$

where f_0 is the funds per unit weight appropriated for the type of device, c is a constant, s is the age of the developing organization at the time this specific development is initiated, a is a constant, r is the length of time the development is to take, b is a constant, n is the number of personnel in the developing organization, and w is the weight of the device. If time be measured in years and weight in tons, it is estimated that c is .2, a is 1.0, and b is .01.

Historical data for testing these equations is difficult to find; appeal must therefore be made, temporarily at least, to reason and this is attempted here by showing what these formulas do and why. The form of the equations (which are not unique; some of quite different form would give closely the same numerical results) and the values suggested for the constants are derived from the author's experience.

Equation 1) says, essentially, that the more lethal a weapon is the more difficult improvement becomes. It further avers that the cost of developing or improving a weapon is proportional to the weight of the weapon. To get some idea of the value of the constant k let us consider the cost of doubling the lethality of a five-ton, self-propelled gun. This might reasonably be \$10,000,000 if the money were used by a perfectly efficient organization. For equation 1) to give \$10,000,000 requires that k have the numerical value of .000032. Now using this value of k , how much would it cost to double the lethality again? One finds \$75,000,000 which appears to be of the right order of magnitude.

Equation 2) says that organizations are less than perfectly efficient and tells how much less in terms of the age and size of the organization and the urgency of the development.

As an organization ages it becomes less efficient for a number of obvious reasons and perhaps more so for reasons less obvious. In the aging of an organization there is a turnover of personnel; the more effective people leave and the less effective stay. It is the engineering version of Gresham's Law; ineffective personnel drive out effective. Further, as the organization ages intramural feuds and struggles for status and prestige take up

more and more of the time and energy of the employees. It has been estimated that in an organization ten years old over 90% of the time and energy of the help goes into these personal struggles and less than ten percent into productive work. Still further, as an organization ages it develops a certain rigidity of point of view; there becomes just one right way to do everything and unorthodox approaches which might be very beneficial to the product are not even considered. All these detrimental factors from aging and possibly others not known and considered here are summed up in the value of the constant c of equation 2) which is believed to be approximately .20.

The faster a development must be made the greater the cost--crash programs are expensive. One reason is that when there is the pressure of haste, things are tried, materials bought, and apparatus built which more mature thought would have shown to be unnecessary. This type of inefficiency is summed up in the constant a of equation 2) which is estimated to be 1.0.

Large organizations are less efficient than small, mainly because as ideas flow up and down through more and more echelons of command they become garbled or altogether blotted out. This effect is summed up by the constant b of equation 2) which is estimated to have the value .01.

The above formulas will now be used to find the actual funds which must be appropriated to double the lethality of the self-propelled gun mentioned above. The cost will be the same, \$10,000,000 for all perfectly efficient organizations but we shall compare the costs of two imperfect ones. The first one is two years old and will do the job in three years. The second is five years old and will do the job in two years. Application of equation 2) shows that the respective actual costs will be \$29,000,000 with 480 people employed and \$58,000,000 with 1,450 people employed. Employees have been figured at \$20,000 per year--this includes capital charges on the facilities they use and the materials expended. It will be noted that formula 2) shows, under certain conditions, indefinitely large costs for completing a project; this means that that particular organization cannot do the job no matter how much it spends, in accord with the facts.

On balance, then, two major conclusions can be drawn from these formulae and the concepts which they express. First, it is a rather expensive business to design from scratch, or to improve, a new and lethal weapon so as to achieve an increase in lethality. Secondly, as organizations grow older, they generally

grow larger, and at the same time less efficient, both of these trends adding further to the cost of development and redesign. There appears to be considerable factual and experimental evidence to support these mathematical conclusions.

Accordingly, in the process of organizing ourself for improvement of the lethality of weapons, we must do our best to guard against the inefficiency, and expense, which are the results of age and of size. Whether this means that our existing organizations must be frequently shaken up and revitalized in systematic and (perhaps) ruthless fashion, or that we should go about our redesign projects with new, or ad hoc organizations, is hard to say. Quite obviously there is some period of time in the early development of new organizations where lack of experience, and lack of teamwork will inhibit efficiency as much as age and size can degrade experience and teamwork. And so, perhaps, the most important thing is to be aware of the facts so clearly presented by our formulae, and be constantly on our guard to prevent them from becoming self-defeating, either in terms of expense or efficiency.

Morale, National Psychology,

and

Weapon Lethality
(Annex III-G)

by

Stefan T. Possony

MORALE ASPECTS OF WEAPON LETHALITY

A military organization collapses, not because it suffers a certain casualty rate, but because its morale breaks. (The proof was presented almost 100 years ago by Ardant du Picq.*) There is no particular percentage "x" of casualties where collapse occurs, nor is there a percentage below "x" where the military unit can be depended upon to remain more or less intact.** Casualty rates affect morale, but the infliction of casualties is merely an indirect method aiming at disrupting organizational cohesion and at paralyzing or diverting the will of the opponent. Accordingly, firepower--"lethality"--is a moral as well as a physical weapon. The person who is hit will consider fire to be a physical phenomenon, but save in exceptional cases the process of killing does not serve to eliminate a specific dangerous enemy, but is undertaken to demoralize those who survive. This has been true over the centuries and remains true even for modern "strategic" air war.

It follows that mere physical lethality can be but one aspect of the effectiveness of a particular weapon. Under

* Du Picq, Ardant, Battle Studies, Military Service, Harrisburg, 1957 (reprint translation).

** However, see the average loss casualty figures in Enclosure 3 to Annex III-H.

certain circumstances, a low casualty rate may be accompanied by considerable demoralization, while a high casualty rate may induce strong resistance. Among the factors which create this seemingly paradoxical result are attitudes toward war, hope for victory, confidence of defeatism, the material and moral situation within the military force, etc., but also the effects of psychological operations accompanying the expenditure of firepower. This is not the place to pursue this particular inquiry further (although it should be noted that the Communists are very knowledgeable on these matters). The point must be mentioned, however, that large numbers of casualties (not fatalities) pose considerable logistical problems; that large numbers of wounded and sick persons tend to affect morale; that the overthrow of the tsar in 1917 and Lenin's seizure of power was facilitated by the fact that the Petrograd garrison was largely manned and officered by reconvalescents;* and that modern means of nonlethal warfare not only would be very useful for certain military missions (e.g., counterinsurgency), but also would lend themselves to imaginative psychological exploitations.

Hence, must we really design a rifle (for instance) to provide an optimal kill probability? Or is a hit not just as good as a kill? If so, does not the "hitting rifle" have many mobility and accuracy advantages over the "killing rifle," including that of allowing more hits? This sort of question becomes more poignant when we consider the characteristics of highly effective modern weapons that could be used by a defender to break up an attack but which should not impede the defender's own mobility or affect his safety.

ETHNIC, NATIONAL, AND RELATED CONSIDERATIONS

The physical characteristics of weapons appear to have some variegated psychological impacts. We know from studies of American crime that negroes seem to have an exceptionally great fear of pistols, while whites show more fear of knives. Some ethnic groups have higher tolerances to pain than others. There seem to be different degrees of fear of particular pains, as well as of death. Occidentals do not seem inclined to seek self-immolation by fire, as some Asians do, while white women show preference for poison. Perhaps the choice of a branch or service

* The morale breakdown in "Merrill's Marauders" in Burma, in World War II, may have had some similar aspects.

by a volunteer is influenced by subconscious preferences for the types of danger or of death. Different ethnic "mentalities" (some features of which may be temporary) affect the thought processes and emotions that are relevant on the battlefield. There also are different attitudes to violence as such, as exemplified by Hindu "nonviolence" and the low esteem accorded to the soldier in traditional Chinese society. The homicide and suicide rates vary significantly between ethnic groups and often the differences are remarkably constant, thus disclosing more basic mental differences. These rates also are affected by fleeting environmental factors--this should be of the greatest interest to military command, because such variations could suggest new types of military action.

On balance, we know very little about ethnic reactions to weapons and their effects.

For the time being, it must be presumed that gas attacks have a particularly demoralizing effect because the fear of suffocation appears everywhere to be greater than the fear of death by bleeding wounds. In more primitive warfare, such as was practiced by the Abyssinians against the Italians, the natives relied heavily upon the fear of castration, which also may be universal. The forms of terror in Vietnam have universal "validity."

In general, it may be presumed that death that comes unseen and in forms that are not readily understood is more terrorizing than familiar types of death. Surprise has usually proved to be effective, but such effects do not last too long and "habituation" sets in. Weapons that are noisy are more terrifying, at least for a while, and night combat seems to be preferred by a few ethnic groups, such as the Japanese--for instance--perhaps because of better night vision.

During World War II, the Nazis occasionally used noise-producing devices in bombing attacks. In 1940 the noise of air bombardment, together with the impression created by a "diving" attack, had demoralizing effects on the French front. But is noise purely psychological or is a physiological effect of sound waves involved? At any rate, noise devices reduced payload, and indoctrination went a long way toward neutralizing their effectiveness, especially after it turned out that the weapons were more noisy than dangerous. The noise attachments to aerial bombs soon disappeared but the Nazis experimented with high frequency sound waves as lethal area weapons. Investigation of this work might be fruitful.

It was also suggested that V-2 attacks against Britain were "nerve shattering" because the "warning" came after impact. It is more than doubtful, however, that this sort of "psychological augmentation" of physical effectiveness really makes much difference. It seems to be far more important to create the impression within the armed forces, and within the society at large, that really huge casualties are being inflicted and that there is no effective defense to preclude future hecatombs, hence "sauve qui peut" is the individual's and the family's rational course of action.

Religious concepts also play a role. For example, during the Indian mutiny of 1857, the British sometimes resorted to the unusual practice of executing rebels by tying them to the muzzles of guns. The notion was that the Indian believers in reincarnation would be more frightened if they were blown to bits than if they were dispatched with their bodies remaining intact.

Presumably, there should be considerable differences in psychological weapons effectiveness between ethnic groups. However, if we review the experiences of the last two world wars, no particular cases come to mind to suggest major differences in national psychology. In air warfare, fire raids were more impressive than H.E. attacks, but they also often were physically more effective, at least in those instances where fire storms developed. Yet it does not seem that the Germans reacted differently from the Japanese or the British. While there was no particular proneness to panic in these nations, there was mass panic in Calcutta, Rangoon, and Colombo under Japanese air attack, in World War II. Panic can occur in all forces and populations, but are some groups more susceptible than others? One would assume so on a priori grounds but documentation is insufficient. In those instances when battlefield panics occurred, unexpected firepower usually appeared suddenly, notably at the flanks and in the rear. Technical, coupled with tactical, surprise is a potent combination.

In general, the moral attitude of civilian populations under fire appears to have been moulded by factors that, so to speak, set the stage for the effectiveness of weapons. The length of the attack had significance, as did fatigue and hunger; but confidence, or lack of it, in one's own weapons and in governmental and command efficiency, probably were the key factors. On the battlefield, after an initial shock, disciplined and trained troops have grown "accustomed" to all types of weapon so far used in battle. But lasting demoralization occurs if there is no effective counter, if further resistance appears useless, and if the command obviously is at wit's end.

Thus, firepower, mobility, and surprise pitted against ineffective command is the chief demoralizing combination, and the effects seem comparable in all races and nationalities. The greatest single and lasting demoralizing effect occurs when there is no chance to defend oneself against a particular weapon, while even a rudimentary capability of defense tends to uphold morale. The generalization can be risked that insistence on fruitless offensive operations with inadequate weapons is a fast way of cracking the morale of the troops that are sent to their death. Political loyalty, or lack of it, often makes a great deal of difference.

Among the major military powers, weapons have been remarkably similar, and no significant differences in their effectiveness has been observed. All advanced nations were able to "take" bombardment in World War II, and all were able to keep discipline even under the most heavy fire. There may be differences in "breaking points," in courage, and the degree of initiative on the battlefield. We do not know enough to venture generalizations.

There are military impressions of long standing that, for example, the British are good in ground defense but poor in ground offense; that the French are best on the offensive; that the Italians are "bad" soldiers, etc.; but such statements must be treated with caution. In World War I, the Hungarians seem to have performed better than in World War II. The Rumanians, generally believed to be useless soldiers, nevertheless fought excellently against the Soviet Union in World War II. In two world wars, the Germans were superior tacticians but do not seem to have had any advantage as strategists. The Russians have yet to display aptitude for naval warfare. Although some of the Soviet minority populations living on the shore provide sailors, the naval command (always in Russian hands) has usually proved deficient. By contrast, the British have a reputation for being superior at sea and in the air, but in different soldiers on land. Seafaring nations tend to be good at naval warfare, mountain peoples at mountain warfare, cattle breeders produce a good cavalry, and industrialized nations are good at "machine warfare," maintenance, and mass logistics.

Even assuming these generalizations are valid as such, are they constants or variables? And if those are repeated types of performance, are their causes to be found in ethnic differences, in strategic traditions, in the continuity of military education and staff planning, in military leadership, in the

interplay between domestic politics and strategy? Or could those aptitudes be changed by purposive action?

We just do not know. There is no particular reason in fact to assume that the lethality problem is affected in any meaningful way by ethnic factors, except that more complicated weapons and use patterns are naturally more suitable for the more mechanically minded nations. Groups with fragile courage and morale are more easily defeated, but it does not appear feasible or advisable to change weapon design according to the moral characteristics of a given opponent. But in planning for particular mixes in concrete situations, moral and psychological factors might be usefully taken into account--assuming the requisite information is available.

Quantification of Factors Related to Weapon Lethality
(Annex III-H)

by

T. N. Dupuy*

INTRODUCTION

In approaching the problem of quantifying factors related to weapon lethality, to the extent historical data and statistics will permit, we have decided to consider this from three different standpoints:

1. The inherent or theoretical lethality of weapons;
2. The actual battlefield effectiveness or lethality of weapons; and
3. The relationship of weapon lethality to the tactical factors of mobility and dispersion.

It is obvious from a thorough review of all of the historical data available for this study that thoroughly reliable, accurate, and complete statistics relevant to the lethality or battlefield effectiveness of individual weapons are simply not available, even for the most recent and best recorded wars of the 20th Century. This fact is emphasized in all prior serious studies involving weapon or casualty statistics.**

Nevertheless, despite the paucity of data, and the questionable and haphazard nature of much that is available, it is

* Considerable theoretical assistance and guidance has been provided by Dr. Edward S. Gilfillan, Jr., who is not, however, responsible for conclusions not yet buttressed by definitive mathematical processes.

** See Bibliography.

obvious from the record, as well as from the efforts made in the works cited above, that there is in fact sufficient evidence to compile statistics and to make quantitative comparisons which are of interest and value not only to the historian, but also to the serious professional scholar of warfare and of military affairs. Save, however, for broad generalities on earlier warfare, which have some relevance to modern war, we came to the conclusion that the validity of our calculations would be enhanced by limiting these calculations to data of the 19th and 20th Centuries.

Accordingly, for the purposes of quantitative analysis and calculation we selected the following wars, and the battles indicated, as possibly offering the most useful data to indicate trends and discontinuities in weapon lethality and doctrinal change for a century and a half:

Napoleonic Wars: Austerlitz, Jena-Auerstadt, Borodino, Dresden, Leipzig, La Rothiere, and Waterloo.

Mexican War: Monterey, Buena Vista, Molino del Rey.

Crimean War: Alma, Inkerman, Balaklava, Siege of Sebastopol.

Franco-Austrian War of 1859: Solferino, Magenta.

Civil War: Shiloh, Antietam, Fredericksburg, Stones River, Chancellorsville, Gettysburg, Chickamauga, Chattanooga.

Seven Weeks' War: Koniggratz, Custozza.

Franco-Prussian War: Worth, Gravelotte, Vionville, Sedan.

Russo-Turkish War: Plevna

Russo-Japanese War: Port Arthur, Mukden, Liao-yang, Sha-Ho.

World War I: Mons, Tannenberg, Marne, Lodz, Verdun, 1st Somme, Chemin-des-Dames (1917), Caporetto, Beersheba, Somme Offensive (1918), Lys Offensive (1918), Megiddo, Soissons, Amiens, St. Mihiel, Vittorio Veneto, Meuse Argonne.

World War II: (No specific battles, since time for analysis was not available.)

Korean War: (No specific battles, since time for analysis was not available.)

It was soon evident that it would be impossible to collect the necessary masses of data, to evaluate these, and to analyze them in a comprehensive manner in the time available for this study. Recognizing that it would thus be impossible to complete a definitive analysis of the three major quantification approaches listed above, we have concentrated our investigation of actual battlefield lethality, and the statistics which have relevance to tactical considerations, to battles from the Napoleonic and American Civil Wars.

The results of these limited efforts have convinced us that this quantification project should be continued, in the depth and scope originally contemplated. We feel that such continued investigation will not only provide very useful general background information for military men and scholars of military affairs, but will also serve the following additional specific purposes:

- a. Development of general military planning factors, tactical and strategic;
- b. Development of improved and standardized inputs for wargaming;
- c. Provide a trend basis for extrapolation of logistical and related factors; and
- d. Ascertain general and national reactions to effects of war.

It is believed that a quote from the conclusion of the Klingberg manuscript, Historical Study of War Casualties,* would be most pertinent:

Military statistics in the past have received little study, when one considers the great emphasis placed on peace time planning--that which immediately follows a war and that which falls in the interim period between war and peace--for the betterment of society. Statistics are constantly available and used from the census and other sources to better the standard of living of the smallest community. While the hypotheses suggested in this study leave much room for further tests and development of other theories for analysis, they do show the great need for

* See Bibliography.

more thorough studies of military statistics, the facts determined from which could be applied to the guidance of strategy during the course of a war. What could be better peace time planning than the proper application of military statistics which would bring about an earlier surrender of the enemy?

PART ONE

The Inherent Lethality of Weapons

Theoretical Considerations

The following is the definition of weapon lethality suggested to HERO by the Chairman of AVTAC in a letter to HERO, dated July 24, 1964:

Weapon lethality: the inherent capability of a given weapon to kill personnel or to make materiel ineffective in a given period of time, where capability includes the factors of weapon range, rate of fire, accuracy, radius of effects, and battlefield mobility.

In the light of this definition, we have attempted to ascertain the inherent (or potential or theoretical) lethality of all important weapons in history on a basis that would permit some kind of relative comparison of such weapons. Any approach permitting a relative comparison of weapons, however, requires establishing some sort of relationship between theoretical considerations and practical effects. Yet inherent lethality and actual battlefield lethality effects do not appear, at first blush, to be relatable in practical, precise, and generally applicable terms. The lethality of a weapon in actual use involves many variables, such as terrain, weather, morale, differing states of training, different qualities of leadership, and the like, which cannot be given precise values in any purely theoretical analysis.* Thus any attempt to mix the theoretical and practical aspects of weapons effects might seem to lead to logical inconsistency.

* Values can, of course, be given to such variables for wargaming purposes, or for other limited, specific purposes. Such values, however, will not have general applicability.

Yet these do appear to be reasons why it would be helpful if the two concepts could be advantageously used together. For instance, it is clear that it will not be possible from historical data to allocate casualties precisely in any battle to different weapons; we do not know exactly how many were killed at Austerlitz by cannon, by musket fire, by bayonet, by cavalry lance, or saber; it is even more difficult to estimate how many among the "missing" surrendered or deserted for fear of specific weapons. Data is slightly more complete for wars of the 20th Century, but still is far from precise. The best we can do is to estimate proportions of casualties on the basis of vague and incomplete evidence (as has been done in Part Two of this paper).

If, however, one is able to ascertain that battlefield lethalties of specific weapons are in some way proportional to the inherent lethalties--from which the variables are eliminated--it would become possible algebraically to allocate the casualties in a specific battle, if one knows how many weapons of each type were used there. There is even a self-checking feature; actual battle casualties can never be negative but algebraic solutions can--if one gets a negative solution he is warned that at least one of the assumptions or data is wrong. The results of such combined-concept algebra might not be right but they at least would be objective and more probable than arbitrary assignments. We think we have moved a long step toward being able to do this.

Having arrived at such a relationship between theoretical and actual lethality, one might even be able to divide the inherent lethality of a given weapon, or of the weapons system, used in a battle, by the calculated battlefield lethality and obtain an effectiveness factor. We have not progressed far enough to do this in this study, but we hope it can be done in the near future. If it should turn out that this factor varies little from weapon to weapon and from time to time, it will be interesting and useful to see how this index can be correlated with the technology of different eras.

The Factors of Lethality

The AVTAC definition suggests that factors to be considered in any quantification effort should include: range, rate of fire, accuracy, radius of effects, and battlefield mobility. Our investigation supports the validity of these as factors to be considered (though with some qualifications) and suggests that the following additional factors also must be considered in any

development of inherent or theoretical lethality capability: number of potential targets rendered ineffective, relative incapacitating effect, reliability, and "overkill." Each of these is considered below:

1. Rate of fire. (For hand-to-hand or pre-gunpowder missile weapons, this would include the number of blows, thrusts, strokes, shots, etc.) This we consider to be the number of effective strikes which a weapon, under ideal conditions, can deliver in a given period of time. We have selected one hour for this purpose, for several reasons, including: (a) this permits consideration of sustained rates of fire for missile weapons; (b) it may permit a comparison with actual, battlefield lethality or effectiveness, testing the assumption that over history one hour per day has been the average direct involvement of individual fighters engaged in important battles. We have taken into consideration common human and technical considerations that would affect rate of fire; we have ignored the logistical problem.

2. Number of potential targets per strike. (This, of course, includes consideration of radius of effects for appropriate weapons.) Most individual weapons throughout history, whether pre-gunpowder missile or hand-to-hand weapons, or firearms of the past five or six centuries, can be expected to hit no more than one individual enemy with each blow or strike, regardless of the extent to which the enemy formation is massed or dispersed. Some weapons, however, have had the capability of incapacitating more than one enemy per stroke, and in order to establish a basis for comparison of the relative theoretical lethality of such weapons, it is essential to establish a standard of target density. We have assumed, therefore, that the comparison can best be made for men in mass formation, each individual occupying an area of four square feet. This permits not only consideration of the relative theoretical lethality of high-explosive shells, but also of the multiple casualty possibilities of the nonexplosive solid cannon ball derived from the combination of its muzzle velocity and weight. (For this purpose we have arbitrarily assumed that the number of individuals in massed formation who could be incapacitated by a single cannon ball would be directly proportionate to the weight of the cannon ball in pounds; thus a 12-pound shot could be expected to mow down a file of 12 soldiers in mass formation.)

3. Relative incapacitating effect. This permits consideration of the fact that blows from some weapons are more likely to be lethal, or incapacitating, than others. Thus statistically

it has always taken several blows from a sword to kill an opponent or to put him out of action for the duration of an engagement. A hit from a cannonball has almost always been incapacitating; a hit from a modern rifle bullet is likely to incapacitate an opponent, but its effect is less certain than the nearby explosion of a high-explosive shell. Suitable factors have been selected in each individual case to reflect the average historical likelihood of an individual blow, hitting a target, to incapacitate the target. (The factors used in this study are not precise, being indicative only, but can be refined by detailed review of suitable records.)

4. Effective Range. This is a difficult factor to handle. It has been suggested that the theoretical lethality of a weapon is in no way affected by its range, so long as it is employed within the limits of its effective range. This would preclude, of course, any comparison of weapons of markedly different range characteristics. The whole purpose of this exercise, however, is to attempt to develop a means of comparing the lethality of weapons of markedly differing characteristics. Furthermore, the AVTAC definition requires consideration of this factor, if a suitable basis for doing so can be ascertained.

There can be no question that a weapon's range has some effect on its practical lethality; certainly a swordsman is put in serious jeopardy by a foe armed with a bow or a gun long before he is in a position to use his sword. Furthermore, history proves conclusively that weapons with greater effective range have been more practically lethal than those with shorter range. This being the case, it seems to be undeniable that one theoretical, as well as practical, effect of range is to give that weapon more opportunity to be lethal or incapacitating than one of shorter range.

There is another important consideration in the range effect of missiles: this is to force all enemies within the effective range of a weapon to take some kind of passive or active countermeasures to protect themselves from the effect of this weapon's employment within its effective range. As a minimum, when a missile weapon is employed, it will force an enemy to take cover, or falter, or to otherwise reflect natural human fear--even though this fear may to some extent be controlled by discipline.

We have not yet arrived at a fully satisfactory means of reflecting this range, but obviously a sliding scale of distance must be used; the problem is to make it slide smoothly and

logically. We have decided to establish as a norm for range the length of a man's arm, which we call Normal Range, with a value of 1, or of 1 yard. This permits us to derive the formula:

(1) Range factor = $1 + \sqrt{k \times \text{Effective Range}}$. Somewhat arbitrarily and intuitively we established the constant k as .001, thus permitting a simple calculation using the range in thousands of yards. Until k can be determined more precisely from analysis of battle or proving ground data, this has seemed suitable. Accordingly we have for the time being rejected another selected formula, which also looks plausible, but is more complicated:

(2) Range factor = Normal Range + $k \log \left(1 + \frac{\text{Effective Range}}{\text{Normal Range}} \right)$
Formula (1) has given results quite consistent with the apparent lethality relationship of the weapons considered.

It should be noted, also, that determination of an "effective range" is not simple. It has been suggested that we should consider both mean range and maximum effective range, deriving different lethality indices for each; we have avoided this, however, as being unduly cumbersome and complex; our objective is to obtain factors and lethality indices which are reasonably accurate, while avoiding efforts at precision which are in effect more precise than our relatively inexact basic data would really warrant.

5. Accuracy. This is the probability that a single blow, aimed precisely at the target, will hit the target. This is a reflection of the inherent qualities of the weapon, and not the user, since human accuracy can be affected by practice, training, excitement, etc. To some extent accuracy will vary inversely with the range--and this is certainly so for any individual weapon and generally within different weapons of the same type. However, the degree to which accuracy varies will be very different between different weapons. Thus it cannot be expressed as a direct reflection of range, but must be based upon the actual performance of weapons. We have tried to apply accuracy factors based upon hit probabilities at mean battlefield ranges.

6. Reliability. This is the factor which takes into consideration such things as misfires, duds, jamming, and the like. Increasing reliability has historically been a significant factor in the technical improvement of firearms, and this is given due weight in our calculations.

7. Battlefield Mobility. This is perhaps the most difficult factor of all to apply to our consideration of theoretical lethality. Mobility is very dependent upon a number of variable factors. We have rejected the idea that capability of a weapon to move about the battlefield will affect its actual battlefield lethality but not its theoretical or inherent lethality. We have arbitrarily decided that the relation of mobility to the other factor considered may be suitably represented by the product of the weapon's theoretical lethality (based upon its stationary characteristics) and the square root of its speed in miles per hour.

8. Fighting Machine Capability. We believe that the concept used in applying battlefield mobility for a single weapon may be adapted to the mobile fighting machine, such as a tank or fighter-bomber, which carries more than one weapon and which also can absorb punishment. This is done by adding the basic lethality indices of all weapons carried by the machine, and multiplying this sum by the square root of the machine's rated cross-country or normal operating speed in miles per hour. An approximation of its ability to absorb punishment is obtained by adding the lethality of the most effective weapon which has no more than a 50% probability of incapacitating the machine with a single hit.

9. "Overkill." We have seriously considered applying an "overkill" factor for such weapons as machine guns and high-explosive projectiles, since these have a tendency to inflict more than one incapacitating wound on a single foe. Certainly there is an enormous and increasing waste of potentially lethal forces through dissipation in the spaces between targets, absorption by inert earth or unprofitable targets, and multiple strikes upon the same target. We have decided, however, not to include this factor, though we believe its effects should be given further serious consideration in future studies. The efficiency with which a weapon performs its lethal or incapacitating work does not now seem to us to be relevant to the issue at hand.

The Determination of Theoretical Weapon Lethality Indices

From the factors discussed above, it is possible to establish theoretical weapon lethality indices for any given weapon of any characteristics. We believe that these indices, in fact, provide reasonably good comparisons of the relative lethality of any two or more weapons.

It should be emphasized that these are indices, to show relative lethality of different weapons and are not tied to rates of fire, periods of time, areas of ground, or the like, even though we may have used such considerations (among others) to develop the indices. The computations for the calculation of lethality indices for a number of important weapons, including all of those considered elsewhere in this report to have had a significant effect upon military affairs, are indicated below:

Hand-to-hand weapons. We have assumed that approximately 100 blows, strokes, or thrusts could be made by skillful individuals with most hand-to-hand weapons. Though there could be differences in minor respects between some of the factors in the cases of different weapons, we have considered that these are likely to be so slight, and to be so mutually offsetting, as not to warrant consideration. The calculations below, then, are for such weapons as pikes, swords, battle-axes, and the like, with no consideration of tactical employment, or effectiveness against possible countermeasures or evasive actions, under ideal circumstances, and assuming that there would be a target available against which each blow could be directed:

1. Rate of fire: 100
 2. Targets per strike: 1
 3. Relative effect: .2 (arbitrarily assuming one blow in five to be incapacitating)
 4. Effective Range: 1 (within effective reach, wielded by hand)
 5. Accuracy: 1 (obviously every hand-to-hand weapon has inherently perfect accuracy)
 6. Reliability: 1 (all hand-to-hand weapons have inherently perfect reliability)
- (Factors 7 and 8 are not applicable)
Calculation: $100 \times .2$: or a Lethality Index of 20

Javelin

1. Rate of fire: 80
 2. Targets per strike: 1
 3. Relative effect: .25
 4. Effective range (20 yards): 1 plus $\sqrt{.2}$, or 1.14
 5. Accuracy: .8 (an arbitrary figure, which may be high)
 6. Reliability: 1
- Calculation: $80 \times .25 \times 1.14 \times .8$: or 18

Ordinary Bow

1. Rate of fire: 100
 2. Targets per strike: 1
 3. Relative effect: .2
 4. Effective range (100 yards): 1 plus $\sqrt{.1}$, or 1.316
 5. Accuracy: .8
 6. Reliability: .95 (to consider possibility of faulty bowstrings, or arrows)
- Calculation: $100 \times .2 \times 1.316 \times .8 \times .95$: or 20

Longbow

1. Rate of fire: 100
 2. Targets per strike: 1
 3. Relative effect: .3
 4. Effective range (250 yards): 1 plus $\sqrt{.25}$, or 1.5
 5. Accuracy: .8
 6. Reliability: .95
- Calculation: $100 \times .3 \times 1.5 \times .8 \times .95$: or 34

Crossbow

1. Rate of fire: 60
 2. Targets per strike: 1
 3. Relative effect: .5
 4. Effective range (150 yards): 1 plus $\sqrt{.15}$, or 1.387
 5. Accuracy: .8
 6. Reliability: .95
- Calculation: $60 \times .5 \times 1.387 \times .8 \times .95$: or 32

Arquebus

1. Rate of fire: (Theoretically 30-40, but necessary cleaning of fouling would reduce this by about 1/3) 25
 2. Targets per strike: 1
 3. Relative effect: .75
 4. Effective range (100 yards): 1 plus $\sqrt{.1}$, or 1.316
 5. Accuracy: .65
 6. Reliability: .65
- Calculation: $25 \times .75 \times 1.316 \times .65 \times .65$: or 10

17th Century Musket

1. Rate of fire: (Theoretically 60, but necessary cleaning of fouling would reduce this by about 1/3) 40
 2. Targets per strike: 1
 3. Relative effect: .8
 4. Effective range (150 yards): 1 plus $\sqrt{15}$, or 1.387
 5. Accuracy: .6
 6. Reliability: .7
- Calculation: $40 \times .8 \times 1.387 \times .6 \times .7$: or 19

18th Century Flintlock

1. Rate of fire: (Theoretically 180, but necessary cleaning, and changing of flints would reduce this by about 40%) 110
 2. Targets per strike: 1
 3. Relative effect: .7
 4. Effective range (100 yards): 1 plus $\sqrt{1}$, or 1.316
 5. Accuracy: .6
 6. Reliability: .8
- Calculation: $110 \times .7 \times 1.316 \times .6 \times .8$: or 47

Early 19th Century Rifle

1. Rate of fire: (Theoretically 60, but necessary cleaning would reduce this by about 1/3) 40
 2. Targets per strike: 1
 3. Relative effect: .8
 4. Effective range (300 yards): 1 plus $\sqrt{3}$, or 1.547
 5. Accuracy: .8
 6. Reliability: .9
- Calculation: $40 \times .8 \times 1.547 \times .8 \times .9$: or 36

Mid-19th Century Rifle with Conoidal Bullet

1. Rate of fire: (Theoretically 180, but necessary cleaning would reduce by about 20%) 150
 2. Targets per strike: 1
 3. Relative effect: .8
 4. Effective range (600 yards): 1 plus $\sqrt{6}$, or 1.775
 5. Accuracy: .8
 6. Reliability: .9
- Calculation: $150 \times .8 \times 1.775 \times .8 \times .9$: or 154

Late 19th Century Breech-loading Rifle

1. Rate of fire: 300 (Cleaning problem relatively insignificant in one hour)
 2. Targets per strike: 1
 3. Relative effect: .8
 4. Effective range (500 yards): 1 plus $\sqrt{.5}$, or 1.707
 5. Accuracy: .7
 6. Reliability: .8
- Calculation: $300 \times .8 \times 1.707 \times .7 \times .8$: or 229

Springfield Rifle, M. 1903 (Magazine rifle)

1. Rate of fire: 600 (Cleaning problem relatively insignificant)
 2. Targets per strike: 1
 3. Relative effect: .8
 4. Effective range (800 yards): 1 plus $\sqrt{.8}$, or 1.894
 5. Accuracy: .9
 6. Reliability: .95
- Calculation: $600 \times .8 \times 1.894 \times .9 \times .95$: or 778

World War I Machine Gun

1. Rate of fire: (Theoretically 24,000, reduced by 1/3 because of overheating consideration) 16,000
 2. Targets per strike: 1
 3. Relative effect: .8
 4. Effective range (600 yards): 1 plus $\sqrt{.6}$, or 1.775
 5. Accuracy: .7
 6. Reliability: .8
- Calculation: $16,000 \times .8 \times 1.775 \times .7 \times .8$: or 12,700

World War II Machine Gun

1. Rate of fire: (Theoretically 30,000, reduced by 1/3 because of overheating considerations) 20,000
 2. Targets per strike: 1
 3. Relative effect: .8
 4. Effective range (600 yards): 1 plus $\sqrt{.6}$, or 1.775
 5. Accuracy: .7
 6. Reliability: .9
- Calculation: $20,000 \times .8 \times 1.775 \times .7 \times .9$: or 17,900

16th Century 12-Pounder Cannon

1. Rate of fire: 5
 2. Targets per strike: 12
 3. Relative effect: 1
 4. Effective range (500 yards): 1 plus $\sqrt{5}$, or 1.707
 5. Accuracy: .6
 6. Reliability: .7
- Calculation: $5 \times 12 \times 1.707 \times .6 \times .7$: or 43

17th Century 12-Pounder Cannon

1. Rate of fire: 20
 2. Targets per strike: 12
 3. Relative effect: 1
 4. Effective range (500 yards): 1.707
 5. Accuracy: .7
 6. Reliability: .8
- Calculation: $20 \times 12 \times 1.707 \times .7 \times .8$: or 229

Gribeauval 18th Century 12-Pounder Cannon

1. Rate of fire: 240
 2. Targets per strike: 12 (This value is reasonable also for effects of early 19th Century black powder shell, or of spherical case or canister)
 3. Relative effect: 1
 4. Effective range (500 yards): 1.707
 5. Accuracy: .9
 6. Reliability: .9
- Calculation: $240 \times 12 \times 1.707 \times .9 \times .9$: or 3,970

French 75mm Gun

1. Rate of fire: 150
 2. Targets per strike: area of burst (2700 square feet/4), or 675
 3. Relative effect: 1
 4. Effective range (8,000 yards): 1 plus $\sqrt{8}$, or 3.83
 5. Accuracy: .95
 6. Reliability: .95
- Calculation: $150 \times 675 \times 3.83 \times .95 \times .95$: or 340,000

155mm GPF

1. Rate of fire: 40
 2. Targets per strike: 10,800 square feet/4, or 2,700
 3. Relative effect: 1
 4. Effective range (15,000 yards): 1 plus $\sqrt{15}$, or 4.87
 5. Accuracy: .95
 6. Reliability: .95
- Calculation: $40 \times 2,700 \times 4.87 \times .95 \times .95$: or 474,000

155mm Long Tom

1. Rate of fire: 40
 2. Targets per strike: 10,800/4, or 2,700
 3. Relative effect: 1
 4. Effective range (20,000 yards): 1 plus $\sqrt{20}$, or 5.47
 5. Accuracy: .95
 6. Reliability: .95
- Calculation: $40 \times 2,700 \times 5.47 \times .95 \times .95$: or 533,000

105mm Howitzer, M-1

1. Rate of fire: 100
 2. Target per strike: 6,750/4, or 1,690
 3. Relative effect: 1
 4. Effective range (12,000 yards): 1 plus $\sqrt{12}$, or 4.46
 5. Accuracy: .9
 6. Reliability: .95
- Calculation: $100 \times 1,690 \times 4.46 \times .9 \times .95$: or 644,000

(Note: This does not reflect the tactical versatility of the American 105mm howitzer due to its high selection of powder charges; this could provide a bonus factor perhaps as high as 10%, in comparison with weapons lacking such versatility.)

VT Fuze

It is assumed that the VT fuze will add 25% to the effectiveness of artillery fire on ground targets and 50% to the effectiveness of antiaircraft fire.

World War I Tank

(Assumes 2 machine guns, a rate of speed of 5 mph, and over 50% ability to survive .30 caliber machine-gun fire.)

1. Weapon lethality: 25,400
2. Mobility factor: $\sqrt{5}$, or 2.19
3. Punishment factor: 12,700

Calculation: $25,400 \times 2.19$, plus 12,700; or 55,600 plus 12,700: or 68,300

World War II Medium Tank

(Assumes 1 machine gun, plus one 3" gun; a rate of speed 30 mph; over 50% ability to survive 3" AT gun)

1. Weapon lethality: 17,900 plus 340,000, or 357,900
2. Mobility factor: $\sqrt{30}$, or 5.48
3. Punishment factor: 340,000

Calculation: $357,900 \times 5.48$ plus 340,000; or 1,963,000 plus 340,000: or 2,203,000

World War I Fighter-Bomber

(Assumes 1 machine gun, plus two 50-pound bombs with areas of burst of 10,000 square feet each; speed, 150 mph; over 50% ability to survive a .30 caliber machine gun)

1. Weapon lethality: 12,700, plus 20,000/4, or 17,700
2. Mobility factor: $\sqrt{150}$, or 12.25
3. Punishment factor: 12,700

Calculation: $17,700 \times 12.25$ plus 12,700: or 229,200

World War II Fighter-Bomber

(Assumes 8 machine guns, plus 2 100-pound bombs with an area of burst each of 15,000 square feet; rate of speed 400 mph; over 50% ability to survive a .30 caliber machine gun)

1. Weapon lethality: $17,900 \times 8$ plus 30,000/4, or 143,500 plus 7,500, or 151,000
2. Mobility factor: $\sqrt{400}$, or 20
3. Punishment factor: 17,900

Calculation: $151,000 \times 20$ plus 17,900; or 3,020,000 plus 17,900: or 3,037,900

V-2 Ballistic Missile

1. Rate of fire: 1
 2. Targets per strike: 282,000 square feet/4, or 70,500
 3. Relative effect: 1
 4. Effective range (358,000 yards): 1 plus $\sqrt{358}$, or 19.1
 5. Accuracy: .8 (arbitrary assumption)
 6. Reliability: .8 (arbitrary assumption)
- Calculation: $70,500 \times 19.1 \times .8 \times .8$: or 861,000

20 Kiloton Nuclear Weapon, Airburst

This calculation considers only the effect of blast of the weapon, without the factor of the delivery mechanism, and without consideration of thermal or radiation effects.

Area of effective burst: $7,920^2 \times \pi$, or 194,200,000

Targets per strike: $194,200,000/4$, or 48,550,000

Note: A straight calculation of the effect of 2,000 pounds of TNT--approximately 100,000 Lethality Index--times 20,000 would have provided a result of 2,000,000,000, thus suggesting a possible "overkill" effect factor of approximately 40, with respect to high explosive.

One Megaton Nuclear Weapon, Airburst

(Same basis of calculation as above)

Area of effective burst: $(5.5 \times 5,280)^2 \times \pi$, or 2,649,000,000

Targets per strike: $2,649,000,000/4$, or 661,500,000

Note: The straight calculation of $100,000 \times 1,000,000$ would have given a result of 100,000,000,000 suggesting a possible "overkill" effect factor of approximately 150, with respect to high explosive.

Summation

Listed below are the inherent or theoretical lethality indices which we have calculated for a number of significant types of weapons of history, from antiquity to the nuclear age. Attached as Enclosure 1 is a graphical representation of trends in the lethality of weapons over the course of history, based upon these indices, plotted logarithmically.

Aside from the potential value of the indices, one significant conclusion emerges from this exercise in quantification: Since lethality is in part a function of the number of targets a given weapon can attack in a given unit of time, tactical mobility, personnel competence and reliability, ease of maintenance, ability to replace crew casualties, and ammunition supply are all important variables, and a sharp improvement in any will be reflected in an increase in actual, or battlefield lethality.

<u>Weapons</u>	<u>Lethality Index</u>
Hand-to-hand (sword, pike, etc.)	20
Javelin	18
Ordinary bow	20
Longbow	34
Crossbow	32
Arquebus	10
17th Century musket	19
18th Century flintlock	47
Early 19th Century rifle	36
Mid-19th Century rifle with conoidal bullet	154
Late 19th Century breechloading rifle	229
Springfield Model 1903 rifle (magazine)	778
World War I machine gun	12,730
World War II machine gun	17,980
16th Century 12-pounder cannon	43
17th Century 12-pounder cannon	229
Gribeauval 18th Century 12-pounder cannon	3,970
French 75mm gun	340,000
155mm GPF	474,000
155mm "Long Tom"	533,000
105mm Howitzer, M-1	644,000
World War I tank	68,300
World War II medium tank	2,203,000
World War I fighter-bomber	229,200
World War II fighter-bomber	3,037,900
V-2 ballistic missile	861,000
20 Kiloton nuclear airburst	48,550,000
One megaton nuclear airburst	661,500,000

PART TWO

Battlefield Lethality and Effectiveness of Weapons

Problems With Statistics

The problem of obtaining accurate and reliable statistics has been mentioned earlier. Confusing and contradictory battle statistics result not merely from the normal tendency of battle reports to enhance the size of the enemy's forces and of his losses, while diminishing one's own; they also are caused by the differing interpretations given available data by subsequent evaluators.*

On top of this comes the problem of comparison of statistics, and the drawing of conclusions from such comparisons. Since it is useful to have comparative data, in terms of trends in casualty figures before the Napoleonic Wars, the nature of the problem will be seen in Enclosures 2 and 3 regarding such trends. Both of these are drawn from the same or similar statistical sources, and are based on exhaustive comparisons and calculations by Bodart and by Dodge.** Enclosure 2 gives casualty trends in chronological terms, Enclosure 3 gives them in relationship to size of units. Bodart's conclusion on trends ignores the very important point that (until the time of the Napoleonic War discontinuity which he points out), armies had increased in size while casualties were declining. Dodge, on the other hand, does not take note of the fact that many of his examples of high casualty figures between smaller units came from periods in which hand-to-hand fighting, and the difficulty of withdrawal by defeated forces, may have caused the rates to be higher than otherwise. His conclusion would seem to be more warranted

* The difficulties encountered by the analyst are discussed by several of the authors cited in the Bibliography to this paper.

** Gaston Bodart and Vernon L. Kellogg, Losses of Life in Modern Wars, London, 1916 and Theodore A. Dodge, Great Captains: Napoleon, Boston, 1917.

than Bodart's however, since his later casualty figures for small units, as well as those of more modern times, tend to support his general observation that small units can sustain a higher percentage of casualties than larger units and still retain combat effectiveness. (Furthermore, there is some evidence that Dodge derived his figures from Civil War statistics, then discovered their broader applicability.)

For reasons indicated earlier, we have had opportunity only for exploration of the quantification of battlefield lethality, or of weapon effects in combat (in distinction from inherent qualities of lethality), of the principal weapons employed in the Napoleonic and American Civil Wars. Because time was limited these were chosen as prime examples (on which there is substantial statistical material) of the relative effectiveness of small arms and of artillery before and after the impact of the conoidal rifle bullet on warfare.

Initially it was thought that the lethality of individual weapons, or of weapon systems, would be calculated on the basis of casualties produced by a weapon or system per day per ton--the weight to include men, weapons, animals, supporting equipment, and ammunition for one day of battle. It was thought that the inclusion of a weight factor would be useful in attempting to relate lethality or effectiveness to logistical considerations. While we still believe that further efforts should be made to establish such a relationship, we have had to abandon the concept for this study, since it was discovered that attempts to include the weight of horses, of forage, and the like, resulted in quantitative distortions of the clear qualitative values and limitations of dragoons, and other forms of cavalry, while it introduced unnecessary and (at least temporarily) unmanageable problems in connection with the lethality of horse-drawn artillery.

Definitions and Assumptions

Accordingly, we have defined battlefield lethality of a weapon as the number of casualties produced per battle day per weapon. This will give us individual battlefield lethality values for each important weapon, or type of weapon, which in turn should be comparable to the lethality indices calculated previously.

Casualties are defined as men, present for duty at the outset of a battle or engagement, who for any reason are not participating at the close of the battle or engagement, either because

they are killed, seriously wounded, captured, or missing. Damage to materiel has not been considered, since no reliable data exists on totals of cannon destroyed and captured.

We have arbitrarily decided not to attempt to weigh our calculations to reflect the duration of a battle. Since there were wide divergencies in the periods of time which individual units spent in intense combat in any given battle, we believe that duration of conflict can only be ascertained as a mean figure if the participation time of individual units is given. This creates some serious problems, in attempting to compare short battles with long ones, but after careful consideration we believe that, with data currently available, comparisons are more meaningful in terms of battles than of days, for most pre-20th Century wars. Further study on this is required.

Napoleonic War Calculations

Enclosure 4 shows the lethality values for muskets and cannon as calculated for a number of selected battles of the Napoleonic Wars. A number of assumptions have been necessary to these calculations:

a. Where actual figures for cavalry strengths are not readily available for any army, we have assumed that cavalry comprised 30% of the force, on the basis of average infantry-cavalry relationships for these wars.

b. Where exact number of cannon are not known, or where reported figures are particularly suspect, we have assumed that there were 3.5 cannon per thousand men, again on the basis of known averages.

c. We have assumed that the artillery component of the armies consisted of 20 men per cannon, to allow for gun crews, ammunition carriers, teamsters, and horseholders.

d. To arrive at a figure for the number of muskets and rifles employed in the battle, we have deducted 10% from the infantry component of each army to account for officers, buglers, bandsmen, orderlies, messengers, and the like.

e. In those instances where armies received considerable reinforcements during a battle, to avoid serious distortions of the results we have averaged the force strength (as at Dresden and Waterloo).

f. It was assumed (on the basis of rather scanty evidence) that 30% of all wounds inflicted were by edged weapons (sabers, bayonets, or lances) and that the remainder were equally divided between cannon and small arms fire.

g. Since surrender or desertion is a moral decision based upon fear, we have applied the percentages for weapons to all casualties, including prisoners and missing.

h. We have assumed that all wounded, as reported, were incapacitated at least for the duration of the battle, and thus lumped all casualty figures.

It will be noticed that these tables also include figures for the battlefield area occupied by each army at the start of the battle or engagement, from which we have arrived at a figure for density of the forces in men per square mile. The area figures are rough estimates, made on the basis of study of maps of the battlefields, and deductions regarding troop locations and deployments as these can be obtained from reliable sources. These figures will provide an order of magnitude only and are at best educated guesses. The averages derived from these figures, however, are believed to be reasonably good indications of average troop densities for the period. These density figures will be particularly useful in the next section of this paper, in establishing quantitative relationships between lethality and such tactical factors as dispersion and mobility.

The manner in which known factors and these various assumptions have been used in order to arrive at the indicated lethality values is shown below in the case of the Battle of Austerlitz. Calculations for all other battles were done similarly.

	<u>Forces</u>	<u>Area</u>	<u>Cavalry</u>	<u>Guns</u>	<u>Losses</u>
French	75,000	13.5	30%	225	7,000
Allied	89,000	13.5	16%	265	27,500

Allied Lethality:

Number of French casualties by rifle $\frac{2450}{62,500}$: .0392/rifle
 Number of Allied rifles

Number of French casualties by cannon $\frac{2450}{265}$: 9.25/cannon
 Number of Allied cannon

French Lethality:

Number of Allied casualties by rifle	9625
Number of French rifles	43,200 : .222/rifle
Number of Allied casualties by cannon	9625
Number of French cannon	225 : 42.80/cannon

Civil War Calculations

Enclosure 5 shows the lethality values for small arms and cannon as calculated for a number of selected battles of the American Civil War. The assumptions used to arrive at these values were similar to those for Enclosure 4, differing in specifics as follows:

a. We have assumed that cavalry comprised 13.4% of each force, since this was a Civil War average.

b. We have assumed 3 cannon per thousand men, again an over-all Civil War average.

c. We have used the following statistical sample of Civil War casualty cases where the type of wounding agent was determined as a basis for allocation of all casualties:*

Conoidal rifle bullet	108,000
Smoothbore Musket, round ball	16,000
Shell fragments	12,500
Canister, grape and cannon ball	359
Explosive bullets	139
Other (mostly saber)	7,002
	<u>144,000</u>

From these figures we have assumed that 5% of all casualties were made by edged weapons, 9% by cannon, and 86% by small arms fire. (We have made no attempt to distinguish between wounds inflicted by rifle musket and those by smoothbore; the former caused at least 90% of all Civil War small arms casualties.)

* Gunther Rothenberg, The Age of Gunpowder, unpublished Ms. for this study, p. 68.

Evaluation

A comparison of the results of eight Napoleonic battles with those of eight Civil War battles does not tell us as much as one might hope. We find that, for the average battle, the Civil War rifle was 1.84 times as lethal as the Napoleonic fusil or flintlock musket, while the Napoleonic artillery piece was 3.4 times as lethal as the Civil War cannon. In the light of what we know about the range and casualty effects of the conoidal rifle musket in the Civil War, something of this sort of relationship would have been expected.

These figures are consistent with the principal difference in the way battles were fought at the beginning and in the middle of the 19th Century. Because of the longer range rifle musket, armies fought at greater distances, which not only kept the Civil War artillery from having the opportunity to have as much effect (a factor built into the calculations, of course) but prevented the rifle from causing proportionately as much execution as might have been expected. This, in turn, tended to prolong the battles, and also kept them from reaching quick and decisive conclusions such as were usually the result of Napoleonic battles. Yet equally obviously, in those instances where major attacks were pushed with determination in the Civil War (as at Malvern Hill, Antietam, Gettysburg and Cold Harbor) defending artillery caused dreadful havoc in the ranks of the attackers.

No attempt has been made here to get a figure of lethality per day, or per hour. Considerably deeper investigation of the length of time individual units were exposed, or engaged in close and fierce combat, would be necessary, and casualty rates of such units would then have to be compared with each other, as well as with the totals. At present, therefore, it seems wiser to compare casualty rates on the battle-by-battle basis, than on a day-by-day basis.

It is then interesting to note that, despite somewhat greater dispersion, and despite the fact that decisive conclusions were less often reached, the average percentage of casualties in the average Civil War battle was almost identical with that in a Napoleonic battle, and the average Civil War army had a very slightly higher total battlefield lethality value, per unit strength, than did the Napoleonic army.

Attempts to relate battlefield lethality values to density of deployment was not particularly revealing, nor was a comparable comparison with the duration of engagements. The very scattered,

and inconclusive results of plotting such data suggest that total lethality (L) may vary inversely as the square root of the duration (t) of a battle ($L = k t^{-1/2}$); or that total lethality may vary inversely as the two-thirds power of the density (D) of opposing troops ($L = K D^{-2/3}$).^{*} Before any such relationship can be suggested firmly, it will be necessary to ascertain facts concerning deployments, density and dispersion in considerably more detail than has been possible in this study, and to be considerably more precise in the exact length of time individual major units were engaged in various battles.

On balance, then, efforts to derive useful, consistent, and meaningful values for battlefield lethality have been inconclusive, particularly when compared with the results of the preceding and following sections of this paper.

On the other hand, it must be realized that these calculations and statistical comparisons are still quite tentative. In the light of the results of the exploration discussed in the subsequent section of this paper, it is believed that more time devoted to this will be rewarding. Obviously more must be done to refine these actual combat statistics because they include, in complicatedly varying degrees and circumstances, many imponderables, such as: density of troops, duration of the engagement, the effects of terrain, state of morale, state of training, countermeasures, differing sizes of forces, different weapon mixes, the quality of leadership, and others. Further, more must be done to compare modern statistics with those of Bodart and Dodge, as shown in Enclosures 2 and 3.

We trust that what has been done here will provide a basis for further exploration and study so that it will be possible, on the basis of historical fact and the best available statistics, to ascertain more about how such imponderables affect the course of battles. In particular it is hoped that patterns of relationships can be found between actual battlefield lethality values, and the theoretical indices, which show so much promise. Such relationships, of course, will be most useful in deriving improved and consistent inputs for military war games.

^{*} The nature of the constant factors k and K will depend on the basic measurement units selected.

PART THREE

Relationship of Weapon Lethality to Tactical Factors

Lethality, Mobility, and Dispersal

There is unquestionably a relationship between the lethality of a weapon and the linear deployment of forces opposing it. This has been clearly demonstrated by dispersal tactics adopted in reaction to firepower in all wars beginning with the American Civil War and is probably demonstrable in earlier warfare as well. There also appears to be a relationship between mobility and dispersal, both laterally and in depth, particularly in terms of the mobility of reserves, whether employed offensively or defensively. Except for mobile weapon machines like tanks or combat aircraft, mobility does not affect the inherent lethality of any weapon, although it does the rapidity with which it can be introduced into combat.

There has been at least one published attempt to define and explore the complex relationship between lethality, dispersal, and mobility by Lt. Col. (then Major) William G. Stewart, CE.* His study has suggested a mode of approach to this question which we otherwise might not have explored.

Stewart concludes that "of the three force characteristics . . . only firepower [i.e., lethality] and mobility are really basic. Dispersion is simply a result of the other two. The enemy's firepower and mobility require us to disperse over a given area. Our own firepower and mobility permit us to disperse over an area, probably different than the first." We agree with this, and have adopted it as an assumption upon which the following discussion is based.

* "Interaction of Firepower, Mobility and Dispersion," Military Review, March 1960.

To determine whether this relationship is reasonably constant, or consistent, we have decided to compare weapon effectiveness, mobility, and dispersion as they have been evidenced in four major periods of historical conflict: the Napoleonic Wars, the American Civil War, World War I, and World War II. The Napoleonic Wars saw the height of compatibility of tactics with the major weapons of the Age of Gunpowder: flintlock musket and smoothbore cannon. The Civil War and World War I were conflicts of a transitional period, in which tactics were obviously not attuned to the implements of war. In World War II, however, once again tactics were obviously compatible with the major weapons being employed: magazine or semiautomatic rifle, machine gun, quick-firing artillery with high-explosive projectiles, tanks, and close-support aircraft.

Thus we can have some certainty that the relationship of the factors (lethality, mobility, and dispersion) was reasonably sound in the first and last of our examples; we must have some serious doubts as to the adequacy of the relationship in the two intermediate examples.

For the reasons offered by Stewart (though we believe these should be explored further in the near future), we have decided to do our comparison in terms of type or average forces of 100,000 men (armies, in the Napoleonic and Civil War eras; army corps in World War I and World War II).

Development of the Factors

On the basis of data compiled in earlier portions of this paper, we have ascertained that the average size of armies in eight important, and typical, Napoleonic battles was 104,150 men, with a density of 12,400 men per square mile, arranged in an oblong formation approximately four times as long as wide, or 5.8 miles long and 1.4 miles deep, to provide an area of 8.4 square miles. A Napoleonic "type" army of 100,000, in this density, and in such a formation, would fit into an area of 8.05 square miles, with a frontage of 5.7 miles a depth of 1.4 miles, and a diagonal of 5.9 miles.

Similar data on eight major Civil War battles shows that the average army was 64,500 strong, with a density of 9,750 men per square mile, still in an oblong about four times wider than deep, or 5.15 miles long and 1.29 miles deep, or an area of 6.63 square miles. A Civil War type army of 100,000 would fit into an area of

10.3 square miles, with a frontage of 6.4 miles, a depth of 1.6 miles, and a diagonal of 6.6 miles.*

We have not had an opportunity to make comparable calculations in this study for World War I and World War II battle deployments; the figures given by Stewart appear to be soundly developed. Thus, for World War I a type corps of 100,000 men is considered to have occupied an area of 140 square miles, with a frontage of 11 miles, a depth of 13 miles, and a diagonal of 17 miles. For World War II a type corps of 100,000 men is considered to have occupied an area of 1,727 square miles, with a frontage of 38.4 miles, a depth of 45 miles, and an average diagonal of 59 miles.

For the purpose of simplicity, and lacking other theoretical tools, Stewart related firepower to areas, which forced him to eliminate nonexplosive firepower. Since nonexplosive firepower accounted for considerably more than 90% of Civil War casualties,** and at least 40% of World War I and World War II casualties, this introduced a serious distortion into his results. By virtue of the calculations which have been made in the two previous sections of this report, we have been able to derive relatively consistent theoretical lethality indices and relatively consistent actual battlefield lethality values for all weapons used in the Napoleonic and Civil Wars. We also have suitable theoretical lethality indices for most major weapons of World War I and World War II, calculated earlier in this paper.

Applying these indices to the weapons available in type army or corps of 100,000 men, we arrive at the following theoretical lethality indices: for a Napoleonic type army of 100,000 men, 5,500,000; for a Civil War type army of 100,000 men,

* It should be noted that there is a slight discrepancy in the shape of a typical Civil War army from that indicated by Stewart, and a very significant difference in calculation of density and the amount of area covered by a Civil War army of 100,000; the figures shown above, however, are not only averages, but also check quite closely with the actual battlefield deployments of Union armies that comprised approximately 100,000 men.

** Casualties produced by artillery were probably not over 9% of total casualties, and of these most were caused by canister or spherical case shot.

14,300,000; for a World War I type corps of 100,000 men, 232,800,000; for a World War II type corps of 100,000 men, 1,280,500,000. (See enclosure 6, "Composition of Type Forces," Enclosure 7, "Comparison of Theoretical and Actual Lethality Figures for 100,000-Man Type Forces," and Enclosure 8, "Comparison of Theoretical and Actual Lethality Figures for Selected Weapons.") It will be noted in Enclosure 6 that we have included tank elements for both World War forces, and an air support element for World War II; failure to consider these would have resulted in serious distortion of figures for the World War II army. The basis for the actual casualty figures for the Napoleonic and Civil Wars is contained in an earlier portion of this paper. The basis for the actual casualty figures shown for World War I and World War II is contained in Enclosure 9, "Casualty Factors for the World Wars." As pointed out in that enclosure, comparability of these casualty figures--and of the lethality values derived from them--is far from certain at this time.

Interrelationships Established

On the basis of the data compiled, we have then listed what we consider to be the "Basic Lethality, Dispersion, and Mobility Factors," in Enclosure 10. From this data the following points are discernible:

In the two periods in which we know that weapons and tactics were fully compatible (Napoleonic Wars and World War II), the average area in square miles occupied by the type force proves to be slightly less than 1.5 times the force lethality index (in millions). For both of the other wars, in which we know that weapons had not been assimilated and in which casualty rates were clearly related to inability to adapt adequately to weapons, the area occupied by the type force proved to be significantly less than the force lethality index (in millions).

The length of time necessary to move reserves into action in World War I was greatly in excess of comparable times for the other three wars. This would go far to explain why it was so difficult to achieve a breakthrough and also why, once a breakthrough was clearly made and exploited, it could not be easily stopped until it faltered from its own frictions and loss of momentum.

These results are, we believe, extremely significant. In the first place, they tend (at least in general terms) to validate the earlier calculations of theoretical lethality indices.

Secondly, they seem to justify the basis we have developed for testing the relationship between lethality, dispersion, and mobility, in varying circumstances and in different time frames. Obviously much more work needs to be done, not only to refine these calculations, but also to test them against other type forces and in other situations. We would like to find out more about the relationship of theoretical and actual lethality figures. For the present, however, it would appear that two major conclusions can be reached:

1. A combat force should be so dispersed that it occupies an area, measured in square miles, at least as large as the value of its own composite lethality index (in millions).

2. A combat force should be so concentrated that its reserves can be committed effectively to any part of its area within a period of approximately four hours.

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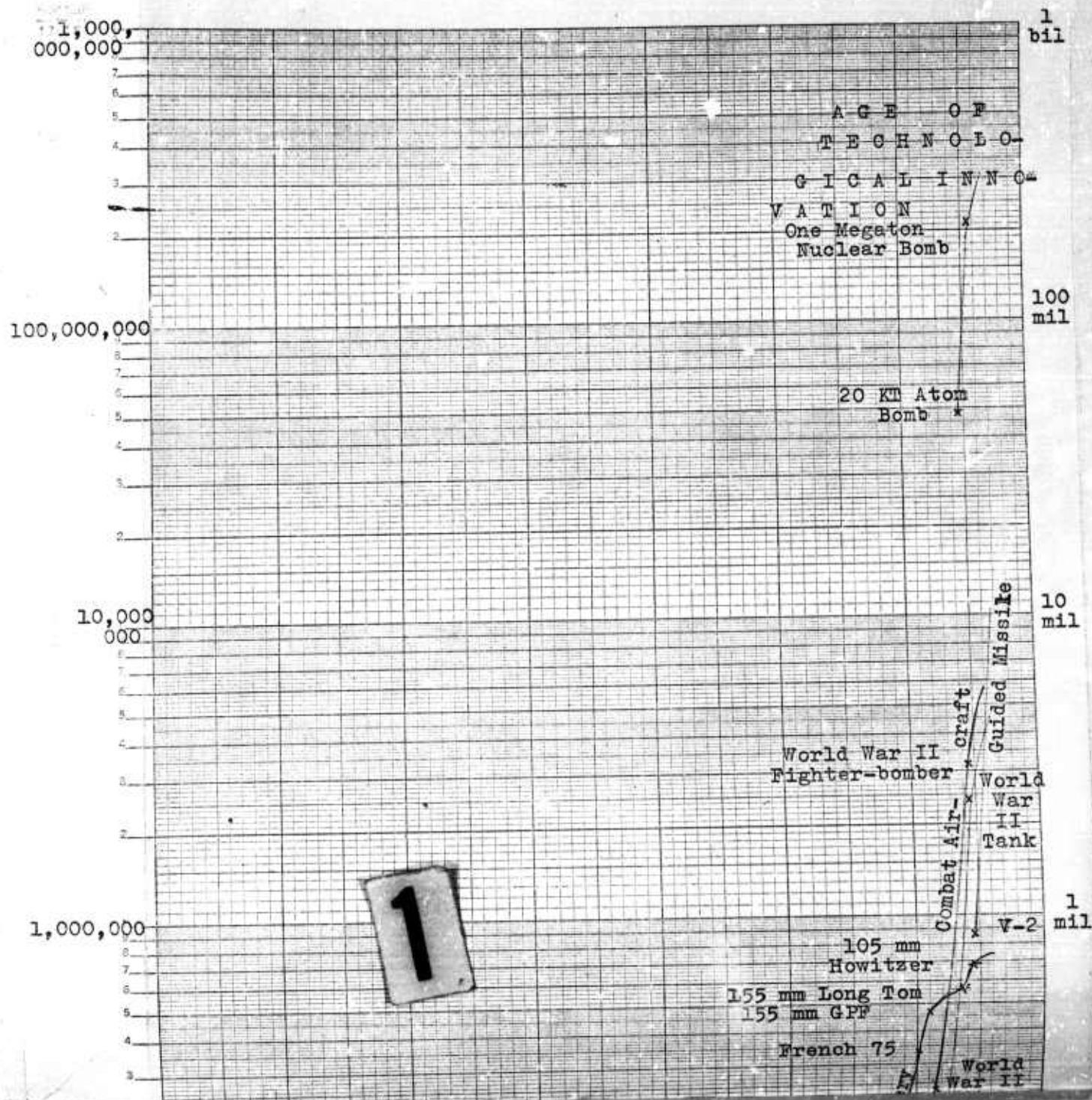
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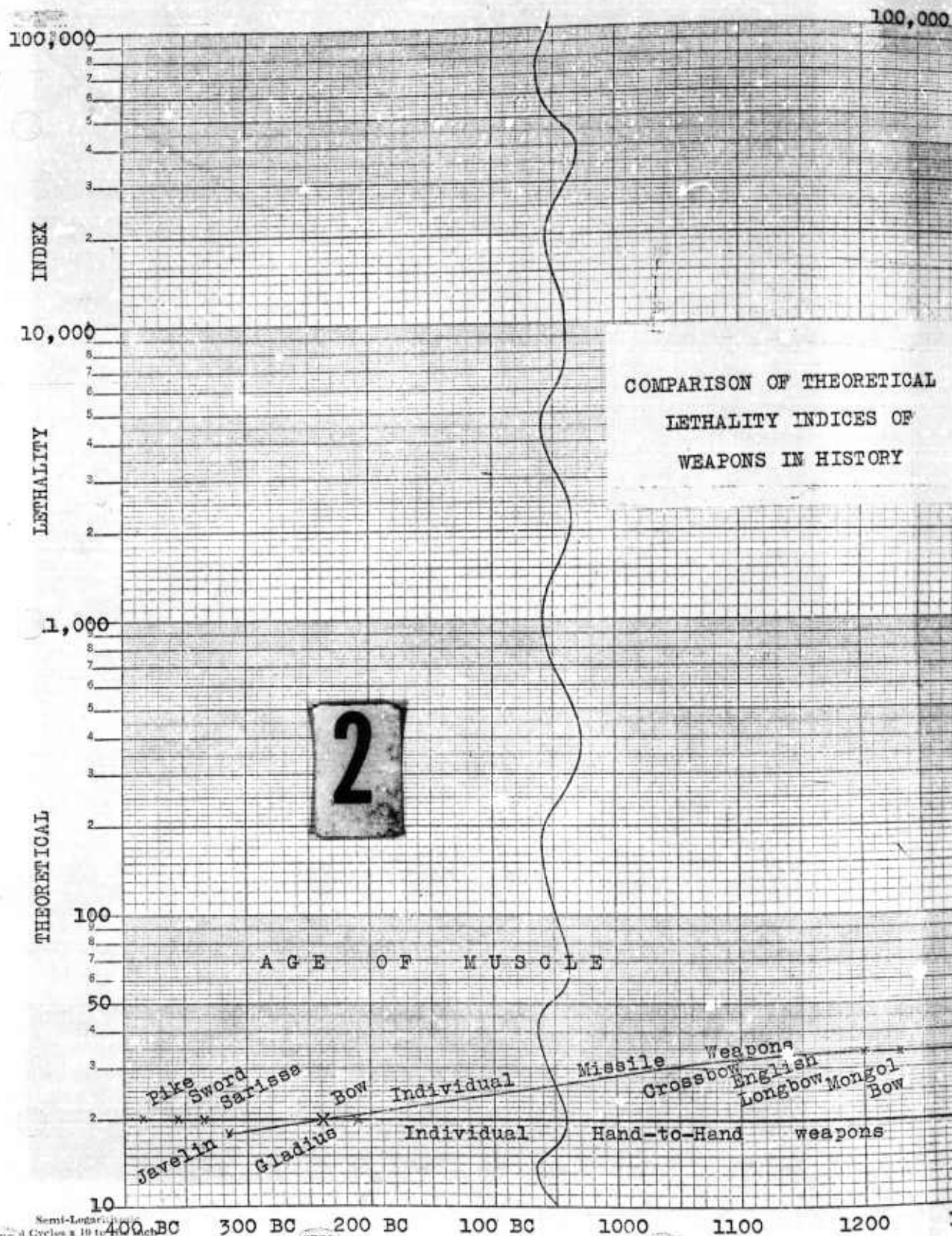
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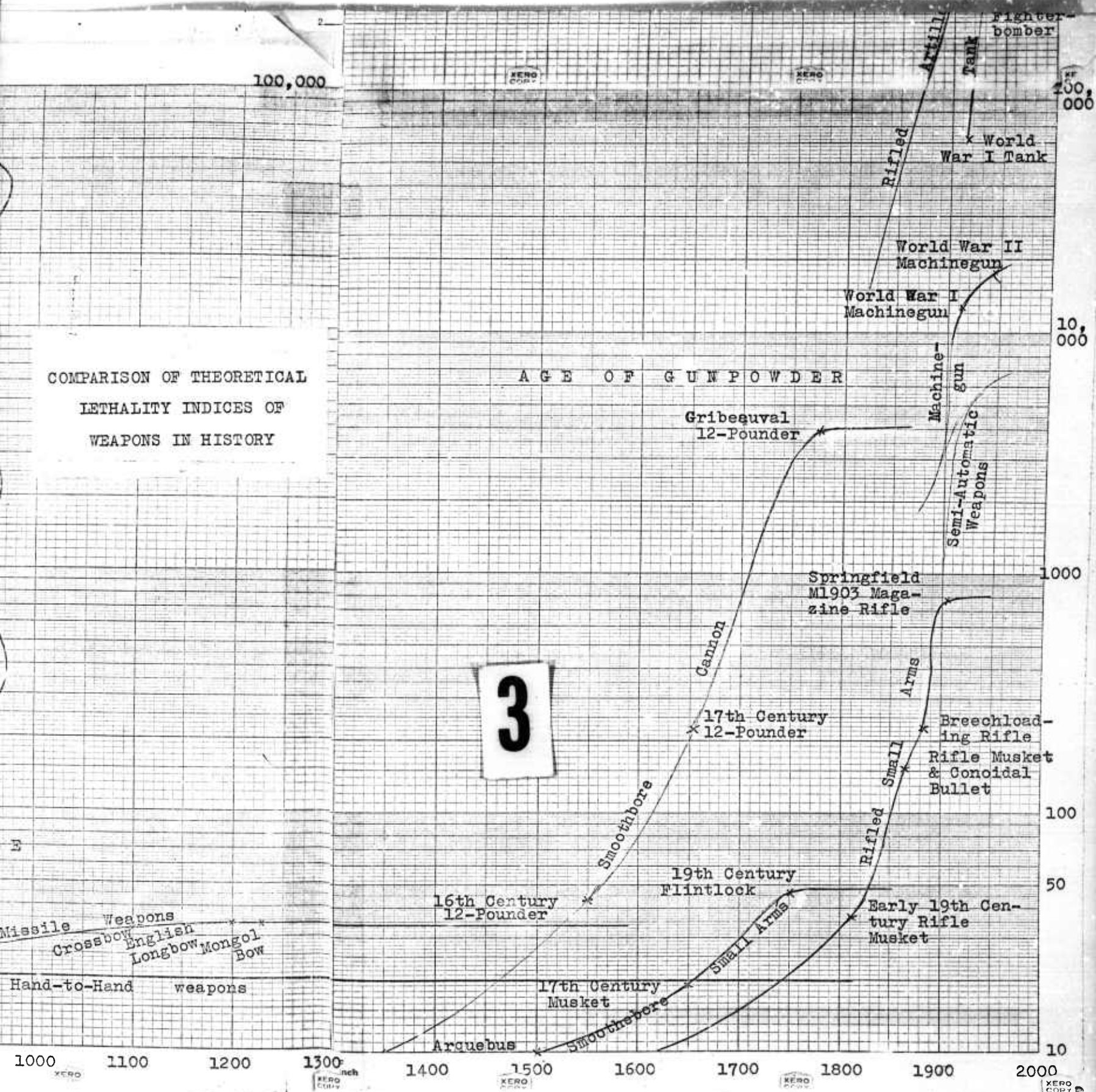
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COMPARISON OF THEORETICAL
LETHALITY INDICES OF
WEAPONS IN HISTORY



Enclosure 2

SIGNIFICANT STATISTICS ON
AVERAGE LOSSES IN BATTLE*

16th Century

Victor's losses: 10% killed and wounded**
Defeated's losses: 40% killed and wounded; few prisoners

Thirty Years' War (1618-1648)

Victor's losses: 15% killed and wounded
Defeated's losses: 30% killed and wounded; prisoners rise
to 10-15%

Wars of Louis XIV (1648-1715)

Victor's losses: 11% killed and wounded
Defeated's losses: 23% killed and wounded; prisoners rise
to 12-20%

Wars of Frederick the Great (1740-1779)

Victor's losses: 11% killed and wounded
Defeated's losses: 17%; prisoners 12-20%

Wars of the French Revolution (1789-1804)

Victor's losses: 9% killed and wounded
Defeated's losses: 16% killed and wounded; prisoners
5-20%

Napoleonic Wars (1805-1815)

Victor's losses: 15% killed and wounded
Defeated's losses: 20% killed and wounded; prisoners
5-20%

* Based on Bodart, through Russo-Japanese War; World War I
and World War II figures are derived from results of this study.
** General ratio of 1 killed to 3.5 wounded applies through-
out.

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* Based on Bodart, through Russo-Japanese War; World War I
and World War II figures are derived from results of this study.
** General ratio of 1 killed to 3.5 wounded applies through-
out.

Crimean War (1854-1856)

Casualties

Killed and wounded: 12%

American Civil War (1861-1865)

Killed and wounded: 14%

Franco-Prussian War (1870-1871)

Killed and wounded: 7.5%*

Turko-Russian War (1877-1878)

Killed and wounded: 13.5%*

Russo-Japanese War (1904-1905)

Killed and wounded: 14%*

World War I (1914-1918)

Killed and wounded: 20.5%** (Ratio; killed to wounded,
1:5.24)

World War II (1939-1945)

Killed and wounded: 18%** (Ratio; killed to wounded,
1:3.4)

* Losses over several days of major battles.

** Based upon single day losses in intensive combat in representative major battles; for World War I this was in the Meuse Argonne offensive, October 1918; for World War II it was in operations in Normandy, July 1944.

Enclosure 3

AVERAGE LOSSES IN HARD-FOUGHT BATTLES
1630-1811*

<u>Size of Force</u>	<u>Percent Casualties killed and wounded</u>
8,000 to 9,000	18
9,001 to 10,000	17
10,001 to 20,000	16
20,001 to 30,000	15
30,001 to 40,000	14
40,001 to 60,000	13
60,001 to 100,000	12
100,001 to 130,000	11
Over 130,000	10

(Ratio of killed to wounded
varies irregularly from 1:3
to 1:3.5)

* Based on Dodge, op. cit.

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Enclosure 4--LETHALITY STATISTICS FOR SELECTED NAPOLEONIC WAR BATTLES

Battle	Side	Forces	Area in Miles ²	Density/ Miles ²	% Cav.	Gun/Man	Guns	Number Rifles/ Muskets	Total Losses	%	Lethality/ Muskets	Lethality/ Cannon
Austerlitz 2 Dec 1805 (8.5 hrs)	Fr* Al	75,000 89,000	13.5 13.5	5,500 5,500	30 16	.003 .003	225 265	43,200 62,500	7,000 27,500	9.3 31	.222 .039	42.8 9.25
Jena 14 Oct 1806 (9 hrs)	Fr* Pr	90,000 50,000	17.5 9	5,150 5,550	30 23	.0035 .0035	315 175	51,030 31,500	7,000 20,000	7.8 40	.156 .077	27.2 14.0
Auerstadt 14 Oct 1806 (9 hrs)	Fr* Pr	30,000 50,000	4.5 10.1	6,700 4,950	30 23	.0035 .0035	105 175	17,010 31,500	7,000 20,000	23.4 40	.411 .071	66.6 14.0
Borodino 7 Sep 1812 (12 hrs)	Fr* Rus	130,000 121,000	6? 7?	21,666 17,300	21 17	.005 .004	650 484	80,730 80,775	27,000 50,000	20.7 41.2	.215 .116	26.9 19.52
Dresden 26-27 Aug 1813 (14 hrs)	Fr* Al	100,000 150,000	6 8	16,666 18,750	20 17	.0035 .0035	350 525	65,700 102,600	10,000 35,000	10 23.3	.186 .034	35 6.66
Leipzig 16-18 Oct 1813 (24-36 hrs)	Fr Al*	180,000 300,000	9 11	20,000 27,270	20 17	.0035 .0035	630 1,050	118,260 205,200	62,000 53,000	34.4 17.7	.156 .105	29.4 20.6
La Rothiere 1 Feb 1814 (7 hrs)	Fr Al*	28,000 78,000	2.5 4	11,200 19,500	23 11	.004 .003	112 234	17,388 58,266	5,000 6,000	17.9 7.7	.121 .030	18.71 7.471
Waterloo 16 Jun 1815 (4-10 hrs)	Fr* Al*	72,000 129,000	4.5 8.5	18,000 15,200	32 22	.004 .003	288 387	38,880 83,592	32,000 22,500	44.5 17.5	.199 .151	36.1 28.8
Averages:	Fr Al Av Type	88,200 120,100 104,150 100,000	7.9 8.9 8.4 8.05	11,200 13,600 12,400 12,400	30+ 30- 30 30		330 412 374 350	51,620 70,800 58,882 56,700	19,600 29,200 24,400 23,400	22.2 24.3 23.4 23.4	.198 .097 .148 .148	30.4 16.7 23.6 23.6

*Victor

Lethality of type army: 21,080
(See Enclosure 7)

Enclosure 5--LETHALITY STATISTICS FOR SELECTED CIVIL WAR BATTLES

Battle	Side	Forces	Area in Miles ²	% Cav.	Guns/Man	Guns	Number Rifles	Total Losses	%	Lethality /Rifle	Lethality /Cannon
Spiloh 6 Apr 1862 (15-20 hrs)	U*	62,682 40,335	5 4	13.4 13.4	.003 .003	188 121	45,470 29,259	13,047 10,694	20.9 26.5	.202 .375	5.12 9.70
Antietam 17 Sep 1862 (12 hrs)	U C	80,000 45,000	10.5 9.5	13.4 13.4	.003 .003	240 135	59,012 32,463	12,410 13,724	15.5 30.5	.200 .329	5.15 8.27
Hedaridsburg 13 Dec 1862 (12 hrs)	U C*	106,000 72,500	10 7.5	13.4 13.4	.003 .003	318 217	76,892 48,600	12,653 5,209	11.9 7.2	.058 .2065	1.47 5.24
Stones River 31 Dec 1862 - 2 Jan 1863 (36 hrs)	U C	41,400 34,732	3.5 3.4	13.4 13.4	.003 .003	124 104	29,135 25,198	12,906 11,739	31.2 33.8	.344 .442	8.49 11.2
Chancellorsville 1-4 May 1863 (36 hrs)	U C*	101,000 57,352	12.0 10.5	13.4 13.4	.003 .003	303 172	73,265 37,914	16,792 12,764	16.6 22.2	.1497 .339	3.78 8.78
Gettysburg 1-3 Jul 1863 (30 hrs)	U* C	88,289 75,000	4 6	13.4 13.4	.003 .003	264 225	64,061 54,405	23,049 28,063	26.1 37.4	.377 .364	9.57 9.22
Chickamauga 19-20 Sep 1863 (24 hrs)	U C*	58,222 66,326	3.5 4.5	13.4 13.4	.003 .003	174 198	42,246 48,149	16,170 18,454	27.8 27.8	.386 .288	9.55 7.34
Chattanooga 23-25 Nov 1863 (14 hrs)	U* C	56,359 46,165	6 6	13.4 13.4	.003 .003	169 138	40,884 33,497	5,824 6,667	10.3 14.5	.140 .150	3.56 3.79
Averages:	U C Av. Type	74,200 54,800 64,500 100,000	6.8 6.03 6.45 10.3			223 164 193 300	53,829 39,843 46,300 72,540	15,323 13,414 14,369 22,290	20.6 24.5 22.3 22.3	.214 .332 .273 .273	5.44 8.35 6.95 6.95

*Victor

Lethality of type army: 25,225
(See Enclosure 7)

Enclosure 6

COMPOSITION OF TYPE FORCES

Napoleonic Wars

On the basis of data reported or calculated in early portions of the study, a typical Napoleonic army of 100,000 men would be composed as follows:

Cavalry:	30,000 men
Artillery:	7,000 men, 350 guns
Infantrymen with muskets:	56,700 men
Others:	<u>6,300 men</u>

Total 100,000 men, 350 guns

Using the lethality indices calculated earlier, this type army has a total theoretical lethality index of 5,500,000, or 5.5M.

Civil War

On the basis of data reported or calculated in early portions of the study, a typical Civil War army of 100,000 men would be composed as follows:

Cavalry:	13,400 men
Artillery:	6,000 men, 300 guns
Infantry riflemen:	72,540 men
Others:	<u>8,060 men</u>

Total 100,000 men, 300 guns

Using the lethality indices calculated earlier, this type army has a total theoretical lethality index of 14,300,000, or 14.3M.

World War I

The data shown below has been compiled from various sources* and is indicative of a type American Army corps of three divisions, organized and equipped as were US forces in the AEF, in France, in 1918.

Infantry Division:	28,000 men, of whom 14,550 were riflemen 72 artillery pieces (75mm and 155mm) 100 mortars (or equivalent), which in turn are evaluated as averaging the equivalent of 10 light artillery pieces in lethality 1,000 machine guns, light machine guns, or automatic rifles
Supporting Corps Troops:	1,500 riflemen 154 artillery pieces (or equivalent) 1,000 machine guns 100 tanks
Totals for type corps:	
riflemen:	45,000
machine guns:	4,000
cannon:	400
tanks:	100

Using the lethality indices calculated earlier, this type corps has a total theoretical lethality index of 232,800,000, or 232.8M.

*Ayres, Leonard P., The War with Germany; A Statistical Summary, Washington Govt. Printing Office, 1919; The Army Almanac, U.S. Govt. Printing Office, 1950; McEntee, Girard L., Military History of the World War, Scribner, NY, 1937; Stamps, T. Dodson, and Vincent J. Esposito, A Short Military History of World War I, USMA, West Point, 1950, etc.

World War II

The data compiled below has been compiled and adapted from FM 101-10, 1 August, 1945, for a type corps of three infantry and one armored division, with attached air support:

Infantry Division: 14,037 men, of these 6,349 riflemen
70 light infantry guns) evaluated
144 mortars) as averaging 1/10
) equivalent
) of light
) artillery
) piece in
) lethality
87 artillery pieces (including
105mm infantry guns)
866 machine guns

Armored Division: 10,670 men, of these 2,040 riflemen
1,841 machine guns
195 light infantry guns and mortars
(equivalent to 20 light artillery pieces)
89 artillery pieces
195 medium tanks
77 light tanks (evaluated as
equivalent to 15 medium tanks
in lethality)
50 armored cars (evaluated as equivalent to 6 medium tanks in lethality)

Supporting Corps 7,300 riflemen
Troops: 430 machine guns
80 artillery pieces
50 tanks
50 supporting aircraft

Totals for type corps:

riflemen:	30,738
machine guns:	5,694
artillery:	537
tanks:	266
fighter-bombers:	50

Using the lethality indices calculated earlier, this type corps has a total theoretical lethality index of 1,280,500,000, or 1,280.5M.

Enclosure 7' -- COMPARISON OF THEORETICAL AND ACTUAL LETHALITY
FIGURES FOR 100000-MAN TYPE FORCES

	Napoleonic War		Civil War		World War I		World War II	
	Theo- retical	Actual Per Battle	Theo- retical	Actual Per Battle	Theo- retical	Actual Per day	Theo- retical	Actual Per Day
Small Arms Lethality for 100,000	2.71M	8,390	11.05M	19,500	40.0M	3,070	28.0M	2,700
Artillery Lethality for 100,000	1.38M	8,250	1.19M	2,065	136.0M	11,300	333.0M	10,800
Cavalry Lethality	1.41M	4,440	2.06M	3,660				
Machine-Gun Lethality for 100,000					50.7M	3,070	86.4M	2,700
Tank Lethality					6.1M	??	649.0M	??
Aircraft Lethality							158.4M	??
Total Lethality 100000 men	5.5M	21,080	14.3M	25,225	232.8M	17,440	1280.5M	16,200

*Figures are included with both artillery and small arms-machine gun totals

Enclosure 8

COMPARISON OF THEORETICAL AND ACTUAL LETHALITY FIGURES
FOR SELECTED WEAPONS

Weapon	Theoretical Lethality Index	Actual Battlefield Lethality Value/day			
		Napoleonic War	Civil War	WW I	WW II
Saber/bayonet	20	.139	.131		
Flintlock Musket	47	.139			
Rifle, musket & conoidal bullet	154		.131		
Magazine Rifle	780			.068	.088
12-pounder Cannon	3,970	23.6	3.31		
Machine Gun (WW I)	12,700			.768	
Machine Gun (WW II)	17,900				.476
French 75	340,000			28.3	
105mm How.	644,000				20.1
Tank (WW I)	68,300			?	
Tank (WW II)	2,203,000				?
Aircraft (WW II)	3,037,000				?

Enclosure 9

CASUALTY FACTORS FOR THE WORLD WARS

Introduction

As noted in the text, we have not attempted an analysis of battle statistics of World War I and World War II as we have done for the Napoleonic and Civil Wars. It did seem desirable, however, to provide some basis for comparison of the casualty effects of weapons in battle in the wars, as well as for comparison with the theoretical lethality indices.

One serious problem in comparison of casualty statistics of different wars is that of the time frame of reference. This problem was noted in connection with casualties of the Napoleonic and Civil Wars, but it was felt that the currently unknown effect of slightly longer average duration of Civil War battles could be overlooked in comparison of statistics of these two wars.

Obviously the length of "battles" in World Wars I and II--often measured in months--is a factor which cannot be overlooked. Part of the problem is the very fact that there is no precise definition of a modern "battle." Added to this is the uncertainty which exists of the moral and physical effects of prolonged battles on participants, and the absence of standards or gauges of intensity of conflict. The impact of the replacement system needs to be noted, as well, not only for its effect on morale, steadiness, and combat effectiveness of units in prolonged battles, but also for the statistical methods of considering replacements. For instance, are they added to the totals of forces originally engaged, or are they ignored, or are forces engaged averaged on a periodic basis? And to which of these possible frames of reference are battle casualties referred in order to obtain percentages? There is not yet a fully satisfactory, and generally accepted, manner of dealing with these issues.

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Accordingly, for the purposes of providing some indication of ranges of casualties for comparative purposes, we have taken losses per 1,000 men per day for a short period of very intensive combat of the US First Army in World War I, and the same army in World War II. During the height of the Meuse-Argonne Offensive, in early October 1918, losses for heavily engaged units were about 20.5% per day, for one, two, or three days. During the height of the Battle of Normandy (not including the first five days ashore after D-Day) losses in units of the First Army, for very brief periods, were about 18% per day.

Recognizing the limited and narrow nature of these statistics for wars lasting several years, involving many nations, in greatly varying conditions of combat, nonetheless, these figures do permit some comparison with battle losses of two earlier wars that (for the periods of the battles) were of a similar order of magnitude.

World War I Casualties

As is made clear in the three medical casualty references*, it is extremely difficult to ascertain the weapon source of wounded casualties in any war (and almost impossible to ascertain for those killed in action), and the two World Wars were no exception, although slightly better data is available for World War II than for World War I. However, using Love, statistics in the Army Almanac, and Table 109 of Vol. XV (Statistics) of The Medical Department of the United States in the World War, Govt. Printing Office, 1925, it is possible to arrive at the following casualty statistics for World War I:

Casualties per 1,000 men per day, in intensive combat:	205
Ratio of wounded to killed in action:	5.24/1

(This is a very high ratio of wounded, much higher than in previous or subsequent major wars, and is primarily due to the high percentage of gas casualties, which had a very low proportion of fatalities.)

*See Bibliography.

Estimated breakdown of casualties per causative agent:

Rifle or machine gun bullet:	30%
High explosive shell	55%
Gas	24%
Other	1%

(We arbitrarily divide rifle and machine gun casualties equally, or 15% each.)

World War II Casualties

There are significant discrepancies between the records of the Southwest Pacific Theater, the European Theater, and the North African Theater, in a number of respects. However, it is believed that the following statistics are generally as accurate as those for World War I, and the averages shown for causative agents are perhaps slightly more reliable:

Casualties per 1,000 men per day, in intensive combat: 180

Ratio of wounded to killed: 3.4/1

Estimated breakdown of casualties per causative agent:

Rifle or machine gun bullet:	30%
High explosive shell:	60%
Aerial bomb:	3%
Other:	7%

(As in World War I, we arbitrarily divide rifle and machine gun casualties equally, or 15% each.)

Enclosure 10

BASIC LETHALITY, DISPERSION, AND MOBILITY FACTORS

Item	Napoleonic Wars	Civil War	World War I	World War II
Area of 100,000 men (square miles)	8.05	10.3	140	1,727
Average frontage of 100,000 men (miles)	5.7	6.4	11	38.4
Average depth of 100,000 men (miles)	1.4	1.6	13	45
Average Diagonal for 100,000 men (miles)*	5.9	6.6	17	59
Lethality Index Totals (in millions)	5.5M	14.3M	232.8M	1,280.5M
Movement rate for major reserves (mph)**	2	2	2	15
Time to cross Diagonal (hours)	2.95	3.3	8.5	3.9

*Maximum distance from which reserves could be committed within the area, or sector.

**For the Napoleonic, Civil, and First World Wars, major reserves within the sector of a 100,000 man force were committed on foot, at an average rate of 2 mph. For World War II, major reserves were committed within such a sector by truck, at an average rate of 15 mph.

Evolution of the 105mm Howitzer Weapon System*
(Annex III-I)

by

R. Ernest Dupuy

A survey of the inception, development, and production of the 105mm howitzer is peculiarly pertinent to the present study. In the first place we have here a rarity--a weapon developed and adopted as a basic weapon during peacetime which, upon proof in combat, needed no further refinement. In the second place, the weapon was merely one of two major products of a broad impulse and progressive trend in American artillery thought and doctrine stressing the importance on the battlefield of flexibility and firepower cum rate of fire.

These factors, corroborated by the theoretical calculations of the inherent lethality of this weapon made in this study, shed light on why its versatility, controlled by new methods of fire direction--both developed independently yet proved amazingly effective in combination**--earned for the piece in World War II

* This case study is the first result of theoretical analyses elsewhere in this study to develop lethality indices relative to inherent lethality of weapons (Annex III-H). The remarkably high index of the 105mm howitzer (greater than for weapons of larger and smaller calibers, yet not reflecting its superb tactical flexibility) aroused curiosity as to how and why this weapon was adopted by the US Army in 1941. This paper is the result.

** Of possible significance in this study in light of its interest in and emphasis on innovation and innovators is the fact that the late General Charles P. Summerall seems to have had much to do with stimulating the inception of both concepts (one of a weapon, the other of technique) and then encouraging the development of both. Further examination of the role of Summerall in the Army, 1918-1931, might be rewarding.

the appellation of "work horse of the Army." For the 105mm gun-howitzer as finally evolved, while lacking the accuracy of the French 75mm gun or British 25-pounder gun-howitzer, and of the 155mm howitzer, yet combined mobility, sturdiness, firepower, and high rate of fire in such proportion as to override the handicap of relatively wide dispersion.

The basic concept of this weapon germinated in our service during the first year of World War I, in the findings and recommendations of the so-called Treat Board--appointed by the US War Department "to make recommendations concerning types of field guns and the ammunition thereof."

This board--Colonel Charles G. Treat, GS; and Majors John H. Rice, Ord., and Charles P. Summerall, FA--after studying operations on the Western front, stressed among other things the necessity in our divisional artillery for a light howitzer with "approximately the same mobility and same range as the 3-in. field gun, with a projectile at least twice as heavy . . . to reach troops protected by light cover and folds in the ground from the flat trajectory of the field gun."*

As we of course know, through factors and circumstances which need no retelling here, American rearmament projects were left far behind, and this nation entered World War I in 1917 dependent upon artillery material furnished by our allies. US divisional artillery in the AEF fought the war with French 75mm guns and French 155mm howitzers.

Meanwhile, a 105mm howitzer had become standard in the Imperial German Army, a fact noted by the now Colonel Summerall when he was sent to Europe by War Secretary Newton D. Baker in May 1917 to analyze the artillery needs of the AEF. His recommendation that a similar weapon be adopted by the US Army was pigeon-holed, however.**

World War I ended with American military thought focussed on the correction of deficiencies in artillery weapons noted in combat. In December 1918, Gen. Peyton C. March, Chief of Staff,

* Proceedings of a Board of Officers appointed by par. 1, S.O. 89, War Dept., 1915. Mimeo, Army Library, Washington, DC.

** Interview with Gen. Summerall by Brig. Gen. S.L.A. Marshall, as related in letter to the writer October 4, 1964. (Hereafter noted as Marshall interview.)

convened a board of officers to make a "study of armament, caliber and type of materiel, kinds and proportions of ammunition, and methods of transport of artillery to be assigned to a field army." Its report, which up to the opening of World War II would be the "incontrovertable authority on armament" of the War Department, was rendered May 5, 1919.*

Members of the board were: Brig. Gen. William M. Westervelt, Ord., president; Brig. Gens. Robert E. Callan, CAC; and William P. Ennis, FA; Cols. James B. Dillard, Ord., and Ralph M. T. Pennell, FA; and Lieut. Cols. Webster A. Capron, FA, and Walter P. Boatwright, CAC. The Board became known popularly in the service as the "Caliber" or "Westervelt" Board.

Its findings were based on exhaustive interviews with and questionnaires answered by officers with combat experience in the AEF during the war. Among the prominent artillerymen of the AEF whose views were canvassed were Gen. Summerall, whose striking innovations in handling the artillery of the 1st Division at Soissons and of the V Corps in the Meuse-Argonne Offensive had gone far to refine the technique of infantry-artillery teamwork; and Maj. Gen. Edward F. McGlachlin, Jr., chief of artillery in turn of the I Corps and of First Army.

At that time US divisional artillery consisted of a brigade of three regiments--two of 75mm guns (totalling 48 pieces), and one of 155mm howitzers (24 pieces). The 155mm howitzer had proved to be too heavy and clumsy for rapid forward displacement, its ammunition expenditure was exorbitant for the result obtained and its rate of fire was too low to produce the volume of fire demanded by combat experience. The Westervelt Board recommended as "ideal" substitute a 105mm howitzer, lighter than the 155mm but heavier than the 75mm gun.

The Ordnance Department, under the enthusiastic drive of its Chief, Maj. Gen. Clarence C. Williams, at once set to work. By 1920 four pilot models had been turned over to the Field Artillery Board for field test.**

* U. S. Army in World War II; The Ordnance Department; Planning Munitions for War, Govt. Printing Office, Washington, DC, 1953, 29 (hereafter entitled PMW).

** Annual Report, Chief of Ordnance, 1920, Govt. Printing Office, Washington, DC, 1920, pp. 20-21.

These first models were unsatisfactory to the Field Artillery. New models were produced (1920-1923) and by 1926 the Chief of Ordnance declared that a "satisfactory model" had been developed and that its production was the "most pressing Ordnance problem."*

In 1926, too, Gen. Summerall became Chief of Staff, bringing to his task, he said, "two ideas on which I was determined--I would get the 105mm howitzer adopted, and also the Christy tank."** However, his goal was not reached. The Field Artillery Board was still not satisfied, apparently because of relatively poor accuracy in comparison with the French 75mm gun, and the Ordnance Department, while continuing to tinker with the 105mm howitzer was hamstrung by lack of appropriations. An economy-minded Administration and a war-weary nation were in no mood to develop armaments. As Summerall generalized the situation in his final report:

"Further discussion is unnecessary to support the general statement that the funds provided have been insufficient for even an approximate realization of the military system contemplated in the National Defense Act."***

So, since stocks of World War I materiel were on hand, they had to suffice--perforce--as "practical" answer to the "ideal" recommended by the Westervelt Board and urged by Summerall.

In the interim, Field Artillery officers were urging the necessity for increased fire power. In particular, Gen. Summerall, just retired as Chief of Staff, in 1931 proposed the doubling of the divisional field artillery strength--from 72 to 144 pieces. He called for 472 guns (including attached corps and army artillery) to support the attack of an infantry division in a 4km front; 88 of these would be 105mm howitzers, a ratio of nearly 19%.****

* PMW, p. 187.

** Marshall interview, op. cit.

*** Annual Report of the Chief of Staff of the Army, 1930.

**** C. P. Summerall, "Organization, Armament and Employment of Field Artillery," Field Artillery Journal, vol. XXI (Sept.-Oct. 1931), p. 513.

Summerall's reiterated thesis had been, and still was, that "if we are to be economical with our men, we must be prodigal with our guns and ammunition."*

Summerall had earlier pointed out that during the Meuse-Argonne operation "all artillery of all types and calibers [in the V Corps] was employed in accordance with the principle of reaching at every moment only those enemy positions from which fire could be delivered upon our infantry at that moment."**

The distressing and frustrating budgetary hobbles on US rearmament remained through the Great Depression and up to 1938, when the war clouds began rising in Europe. However, the Ordnance Department had been able to make five successive experimental models of the 105mm howitzer, each to be rejected in turn by the Field Artillery Board.

With the outbreak of World War II in Europe, increased awareness on the part of the American people resulted in increased Ordnance budgets. Agreement between the Ordnance and the Field Artillery on the 105mm howitzer was now almost complete; however the Field Artillery still insisted on certain refinements in the carriage. but the crying need of Great Britain for weapons supply from the United States resulted in mounting pressure that the 105mm howitzer go into mass production "as is."

The argument came to a head at a meeting in the office of War Secretary Henry L. Stimson. There British officers argued that if the 105mm could not go into immediate production, the British 25-pounder should be substituted. Maj. Gens. Robert M. Danford, Chief of Field Artillery, and Charles M. Wesson, Chief of Ordnance, strongly disagreed. Stimson decided in the Americans' favor.***

As a result, speedy refinements were made by the Ordnance Department, and in March 1940 the sixth model of the piece--M2A1 --was officially adopted and went into immediate production.

* C. P. Summerall, lecture, V Corps Hq., AEF, 27 Jan. 1919.

** C. P. Summerall, lecture, Army Center of Artillery Studies, AEF, December 16, 1918.

*** Maj. Gen. Robert M. Danford, USA, Ret., in interview with the writer, October 1, 1964.

It is interesting to note that the time lag in the adoption of the 105mm howitzer--22 years--closely follows the norm of the 20-year cycle which appears to limit modern weaponry production. However, in this case the delay came not through diffidence of the using service or reluctance of the military to adopt an innovation. The delay was caused by budgetary restrictions, plus the possession in US arsenals of large stocks of World War I type weapons.

Lethality in Tactical Nuclear Warfare*
(Annex III-J)

by

Stefan T. Possony

The employment of nuclear weapons in ground battle presents many problems unprecedented in the history of warfare. However, two factors of great significance at the present time, may ultimately be eliminated because of technological progress:

First, there is the technical fact that--other things being equal--a smaller yield is more costly in terms of fissile materials than a larger yield. Given a certain amount of fissile material, both a higher and a lower yield can be attained. If higher kilotonnage is desired, this can be achieved with fewer larger weapons at lower cost than would be possible to achieve with a larger number of smaller weapons. If a given stockpile is to be used for the production of small weapons only, its total kilotonnage will be lower than if larger weapons were procured. The cost penalty of the nuclear weapons gets increasingly severe as the yield gets smaller, whereas in past wars a larger explosion always was more costly than a smaller explosion; and cost was roughly proportional to the weight and power of the explosive.

There are a number of reasons why nuclear yields must be kept below certain values on a battlefield. A large yield would pose the danger of killing friendly troops; conversely, if only larger weapons are available, considerable constraints would have to be placed upon tactics to avoid the hazard of "self-damage." For example, friendly troops may have to be kept back at a considerable distance, with the result that the effects of the nuclear burst on the hostile force could not be exploited rapidly, nor to full advantage. Moreover, larger yields could

* See also, T. N. Dupuy, "Can America Fight a Limited Nuclear War?", Orbis, Spring 1961.

create radioactivity which might hamper operations, and they might kill friendly civilians that could otherwise have been protected.

Second, largely because of the high cost of low-yield devices, nuclear weapons today can be used only as "special weapons." This means that--other things still being equal--there will be a trend to use the most "economical" yields (several KT's and up to tens of KT); that these special weapons will be used only against "special," particularly renumeration (or particularly dangerous) targets; that there can not be a high or sustained rate of nuclear fire; and that the really small sizes (e.g., ten tons) cannot be used extensively, and certainly would not become "standard" weapons. At the same time, very small-yield weapons are not likely to be really useful against dug-in and dispersed infantry (except, perhaps, for blinding).

The precise timing of nuclear detonations may pose many difficulties, with the result that such weapons cannot be used "optimally." Note that in this context lethality is a function of optimal timing and that we have no more advanced method than Napoleon's coup d'oeil to choose the most propitious moment; except that timing from a dug-out is a more difficult feat than timing from an elevated observation point. This difficulty suggests the need for entirely new approaches.

The nuclear constraint might be loosened if a new technology (e.g., all-fusion weapons) should make possible the production of cheap and very low-yield nuclear explosives suitable for firing at "short" intervals. In the interim, however, operations requiring sustained fire, must be entrusted to conventional weapons. Thus, although in the face of a nuclear threat we no longer can have the "concentrated force" of World War I or II, we are as yet in no position to disperse unduly on the battlefield, because a dispersal that is too wide would render conventional firepower ineffective. Thus, protection must be sought in deep digging and in deep echeloning. This trend, presumably, would force the yields of tactical weapons upward.

The need to combine nuclear with conventional arms has considerable implications for all the required weapons systems. Since nuclear weapons exist, reliance on the bulk logistics that we had in World War II would be hazardous. There is a need for high mobility, such as is provided by helicopters or tanks, and undoubtedly there is a major need for fast protection techniques, notably earth-moving and digging equipment.

But the crucial point seems to be that, for heavy weapon support, the forward units must be able to call on firepower from protected positions far in the rear, and that no dense or sustained nuclear support fire can be provided. The desired points of impact for nuclear support weapons would have to be defined with enormous and perhaps unattainable accuracy. Moreover, many of the targets may be in motion, and friendly troops may be moving also. Hence yields should be high, but to avoid the killing of friendly troops they must be low. The practical meaning of this paradox seems to be that the heavy rear-positional weapons must direct their fire predominantly against more or less fixed targets in the enemy rear but cannot be used in the actual battle zone until it is presumed that a friendly position has been wiped out or removed from the area.

Under such circumstances, the forward lines will have to place their main reliance on light and small weapons. These weapons must have good rate of fire capabilities; their range should be in the upper limit of the useful infantry range; there must be weapons with armor-piercing characteristics; there should be minimal logistics and maximal mobility. To rephrase this in a slightly provocative way: the infantryman must be equipped with a weapon, or a family of weapons, to allow him to fight effectively and for many hours without support of heavier nuclear weapons.

It is, however, questionable whether such effectiveness is just a matter of increasing "lethality." Once a certain level of lethality has been reached, the premium would seem to lie on weapons and ammunition that can sustain a high rate of fire on the basis of minimum logistics. But there is the additional requirement that the defending infantry also must be able to destroy armored vehicles and aircraft. Unfortunately, a "protection" and "mobility" are dependent upon rather elaborate logistics.

It may very well be impossible to fill these requirements which seem to call for a miracle rifle, a plastic machine gun, a light metal antitank weapon, a two-pound grenade-thrower. The point is that, on a nuclear battlefield, the infantryman needs far more sophisticated and effective armament than the footsoldier of earlier wars. Furthermore, there arises the need for a "complete arsenal" per strong-point. The unit that requires balanced armament no longer is the division but the platoon or the squad.

To clarify the weapons requirements, a clearer distinction between offensive and defensive operations must probably be made. For instance, in defensive operation presumably the infantry would be dispersed over a seemingly "empty" battlefield and deployed in small "complementary" groups, in deep foxholes and pillboxes. Each unit would possess considerable ammunition reserves. Presumably there would be some infantry-range nuclear weapons, with larger yield weapons available on call from the rear. The deployment would be in considerable depth.

Disregarding the effects which a hostile preparation could have on such a defensive position, we could envisage the following types of attack:

First, the attacker concentrates; this concentration is discovered by air or ground reconnaissance, and can be broken up by heavier weapons called in from the rear.

Second, the attack force remains in its positions to the last minute but its offensive intent has been discerned by one or more intelligence means. To pin it down and cripple it, fire would have to be accurate and fairly heavy. This fire could be by means of rear-positioned missiles or aircraft but the premium would be on target intelligence, thus on air and ground reconnaissance.

Third, the attack force has started moving and at intervals is exposed. It also is moving closer to friendly troops. In this case reliance must be placed on infantry weapons, possibly including an appreciable number of low-yield nuclear weapons; these weapons must be fired most accurately to avoid "self-damage." But this accuracy is dependent upon the infantry being able to pin-point the optimal impact positions. Among other requirements, this calls for dependable battlefield communications, for fast reaction times, for an original positioning of defended locations such that the attack force is "channelized," and for infantry with excellent training and discipline.

Thus, yield per se is not the controlling factor. But we should reiterate the importance of a technology that would allow rapid adjustment of yields to situations.

If the attacker's preparations for the assault were not noticed until a major attack was actually launched, the local commander would probably have to use nuclear weapons immediately, but to avoid killing his own troops he must rely on exceptionally small yields. Since the size of the attack force might be strong

enough to permit saturation tactics, the defender would need a large number of such weapons to be used in succession. Obviously, in a melée situation, high (or overkill) lethality would be self-defeating.

But in addition to having small nuclear weapons in large numbers, the premium would be on concealment, notably of the nuclear firing positions, on the skillful direction of the nuclear fire, and on battlefield mobility. The infantry would also need highly effective conventional weapons, first, to force enemy to concentrate in front of obstacles, second to pin him to the ground and slow his advance, and third to punish him when digging in. In such a situation the defender might find it useful to accentuate the melée to prevent the attacker from using large-yield weapons. Thus, every strong point must have considerable self-defense capabilities.

An attacker might use infiltration tactics and attempt to wipe out a maximum number of strong points, probably at night. Since the defensive positions must be concealed against aerial reconnaissance, barbed wire cannot protect them against stalking footsoldiers using hand-grenades. Warning devices that are flush on the ground would have to be used at 360 degrees around the strong points, and must be capable of indicating the precise position of the infiltrators. The counterweapons presumably need not be too different from conventional infantry arms, but small mines and boobytraps would appear to be quite useful.

Infiltration attacks also may be directed against re-supply activities which presumably would be carried out at night by means of jeeps and helicopters. Hence this sort of infiltration attack would benefit from the noise of engines. Accordingly, to assure adequate logistic support, the defender would have to resort to extensive patrolling, flares, counterinfiltration, mining, etc. Again, the premium would not be on lethality, but on mobility, accuracy, and volume of sustained fire (when needed), excellent communications, and a capability to direct accurate fire from supporting units. If mines were used, it should be feasible to place and remove them within a short time.

The corollary to these defensive requirements and capabilities is an effective offensive tactical system to employ against a comparable defensive position. The first requirements would be to determine the deployment of the defender, to assess the vulnerability of his positions, to estimate the precise hazard from enemy nuclear fire, to select the targets or impact points,

and to choose the proper yields. If there are highly accurate missiles, it would perhaps be desirable to eliminate enemy anti-aircraft weapons at an early stage, perhaps with conventional warheads, permit aircraft subsequently to execute pinpoint attacks against the major positions.

If there is an upper limit on the yield of the weapons that are to be used offensively, and presumably there would be, they should be placed in such a way that, with a given average yield, a maximum number of positions would be destroyed per minimum number of nuclear weapons. Other things being equal, the ratio between weapons and targets would vary with the physical characteristics of the defensive field fortifications, the dispersal and concealment pattern, and terrain. Given an approximate limit on yield, the key variables in addition to numbers, are heights of burst and choices between atmospheric, surface, and sub-surface shots. This presupposes flexibility in terms of fuzing systems and the shapes of the outer shells.

On the other hand, if reconnaissance yields inadequate information, or if there is no time to execute this elaborate type of attack, the offensive commander may decide to resort to shock tactics. Undoubtedly, multimegaton weapons could pulverize defensive positions, and if friendly forces could rapidly be thrown into the gap, the terrain could be occupied and a breakthrough accomplished.

In such tactics, however, there might be troubles arising from radioactivity. The very size of the explosions might indicate the center of gravity of the offensive, thus weakening the element of surprise. If the positions were well prepared, a counterattack or defensive capability might survive despite the high yield. Upon penetration, a counterattack with heavy weapons from rear positions should be feasible, because fear of killing friendly troops would be reduced or eliminated.

In any event, the purpose of a nuclear shock ground attack could not be achieved by maximizing the yield, but rather tailoring it to the precise width of the corridor that is to be achieved.

Instead of using atmospheric shots with large yields, it might be preferable to keep the yields relatively low and apply a large volley of sub-surface bursts. In such a situation the neutron weapon, which possesses lethality against protected humans but has virtually no destructiveness, would be of great significance. Not the least advantage would be that the defender's weapons could be turned around. Hence, appreciable

savings in logistics could be achieved and firepower temporarily be boosted.

Nevertheless, it would be imprudent to assume that the attacker would not use large yields. Consequently, survivability on the battlefield is crucial. Since at best only small numbers would survive, the capabilities of each unit, platoon, or squad would have to be optimized; and there must be the capability of bringing up reserves very rapidly. In turn, the attacker in penetrating the "pulverized" position must be able to subdue the surviving defenders who--under the circumstances--could use nuclear weapons far more freely, if they still had them and if those weapons had not suffered radiation damage.

Once a breakthrough should be achieved and "pursuit" or "exploitation" undertaken, there would be little further need for large yields, but rather for small and highly mobile weapons that can be used at an instant's notice to destroy pockets of resistance. The pursuing force needs mobility, high rates of fire, means of protection, and dependable communications systems. Unlike the systems that were used in World War II, the pursuit force need not be loaded down by very heavy equipment if instead it can rely on nuclear weapons. However, the force does require a highly developed capability for very rapid, cross-country dispersal and digging-in.

Moreover, since--under the threat of nuclear counter-attack--pursuit cannot be risked by means of large and tight formations, there is a need for small and self-contained units that can be replaced easily. This is just another way of saying that the small unit must have the range of power of a big unit. Thus, on a nuclear battlefield there is not only a continuing need for conventional arms, but also for vastly improved nonnuclear weapons.

It is generally presumed that in future warfare offensives will move very rapidly. But under conditions of nuclear ground battle this may not be the case. There are factors which suggest that a nuclear ground battle might develop somewhat according to the "orderly" and "systematic" pattern of the battles of 1916 and might resemble the 1940-1941 pattern only if and when the defender is outarmed and demoralized. The point is that while the nuclear weapon has unprecedented offensive power, it also allows most potent counterblows. The key problem --whether a counteroffensive remains feasible after attack--cannot be solved merely by increasing lethality. The solution depends primarily on survivability.

This paper has not been prepared to express definitive judgments on future tactics and weapons systems. Its purpose was simply to explore whether or not lethality should be considered the prime characteristic to which the designer should subordinate all or most other performance features. From this the following tentative conclusions emerge:

1. The concept of lethality, in many instances, is far too vague to serve as a firm criterion; in other instances the increase of lethality beyond a certain point does not seem to provide advantages but may compete with equally crucial purposes.

2. In previous times, major increases of lethality and destructiveness--"sheer explosive power"--were of paramount importance. At present, "sheer lethality" has become an "asymptotic value," i.e., further increases are less important than other improvements.

3. In terms of tactical nuclear weapons, one requirement is for "tailoring" the yield according to target characteristics and tactical situations.

4. Another requirement is to distinguish most carefully between the various types of kill probability and to design weapons for the specific types of lethality required (e.g., earth-protected and armor-protected targets).

5. The main function of the infantry on a nuclear battlefield may be to pin down rather than to kill hostile troops, granted that pinning down presupposes lethal weapons.

6. While we cannot forego the design of general purpose weapons, the missions of modern warfare are attaining an ever higher degree of specificity. Accordingly, there seems to be an increasing need for special purpose weapons, including weapons which allow flexible use of different types of ammunition, including, if at all practical, "double-purpose" nuclear and nonnuclear firearms.

There are no "optimal" answers that would cover more than a highly limited number of situations. Attempts to simplify the problem by restricting the number of variables and assigning numerical values to each variable--and to select such values without regard to specific tactical problems--must lead to trouble. There is no reason not to compare weapons with weapons: such comparisons improve technological insight. But the true measurement is that of the "fit" between the weapon and its

function and between the systematic capability and the tactical requirement.

The Navy learned that to operate at top efficiency, forces should be specifically put together for a clearly defined purpose; each mission called for a differently composed task force. This task force concept has been applied to some extent to modern land battles and may be further developed so that mixes between nuclear and conventional arms, and the combination between lethality and other types of performance, can be changed with the mission, particularly since offensive and defensive tasks call for different mixes of arms.

In terms of design requirements for nonnuclear weapons, this discussion leads to the conclusion that new approaches must be sought. It is not implied that really new approaches can be conceived. Certainly, the concept of most potent, extremely light-weight one- or two-man weapons has been known for more than 30 years to those who have been engaged in the design of airborne munitions. This problem, however, has become more poignant because of the emergence of nuclear weapons and the consequent need to adjust conventional weapons to the requirements of nuclear battle. If, for example, it were feasible to use light metals for ammunition even at the price of reduced lethality, if cross-country mobility could be increased and fuel consumption be decreased, and if we could find substantially more effective and more rapid methods of digging holes (e.g., through jet devices) and of covering them with portable protective materials, we should gain far more than by just increasing one-shot lethality.

Finally, it should not be forgotten that in nuclear battle the ultimate premium will be on morale.* The greatest progress in military effectiveness can be achieved most cheaply through better training and better marksmanship; through the willingness of the soldier to make the best use of the weapon he has and through his readiness to fight and kill; through self confidence and through moral will of such strength that even under the extreme conditions of nuclear fire, the force will continue to have in a disciplined and purposive manner. There is not much one can do with a "mass soldier." The lethality of a weapon once it is good enough to hit and hurt a target, is a function of individual valor.

* See Dupuy, op. cit. regarding some related problems of morale.